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THROUGH THE EYES OF THE EDITOR

Wilfred Hall Terrell develops some excellent arguments for the prominent place for immediate denture service in modern dental practice. He emphasizes the importance of pre-extraction records. Then he gives his complete technique for this service, from examination to occlusion and care after insertion. He uses no labial flange on the immediate denture, and this may be open to question. Otherwise, in our opinion, the procedure is sound.

Jonathan Forman is a national authority on nutrition and allergy. He calls attention to the serious problem of conservation of our soil resources which has a very direct bearing on the dental health, as well as the general health, of the people. The loss of necessary elements in the soil is shown to be a critical factor in the dental restorative problem.

C. H. Blanchard recognizes the importance of an adequate nutrition for adequate denture service. He suggests specific food supplements for patients who are edentulous. He insists that healthy tissues are necessary for the support of dentures. He then proceeds to list and outline the various requirements of restorations. In his discussion of occlusion, he analyzes the functions of cusps of teeth and presents his conclusions regarding the old problem cusp or cuspless teeth. He also discusses the history and development of metal insert teeth. Throughout, he stresses the importance of choices made because of the conditions presented by the patient.

Frank C. Hughes gives simple, sound, and logical answers to many of the problems in prosthetics which may confuse the general practitioner. He stresses the importance of a reliance upon fundamentals. He emphasizes both the psychologic preparation of the patient for prosthetic service and fine esthetic effects as being extremely important to successful denture service.

D. B. Mahler has attacked a vexing problem in the construction of dentures. The "open flask" has been one of the headaches of the technician as well as of the dentist. Many occlusions perfectly balanced in wax have been destroyed during the processing of dentures. The author has carried out scientific experiments to find the cause of this difficulty. He devised a means for measuring the pressures exerted inside the flask, during closure. These pressures were found to be quite considerable. A reduction of the amount of pressure used is indicated to reduce the amount of flask opening.

Ben R. Bronstein discusses the tenets of the various schools of thought regarding occlusion. He states his definitions of terms so there will be no confusion as to his meaning. Then he compares the various ideas on occlusion. His analysis of overloading is particularly interesting to those who do mouth rehabilitation.

A. Yurkstas, H. H. Fridley, and R. S. Manly have attempted to get factual information regarding the relative efficiency of fixed and removable prostheses. They first constructed removable prostheses and tested them for chewing efficiency. Then they made fixed prostheses for the same patients and repeated the tests. It was established that there was little difference in the efficiency of the two types of appliances. It seems important to note, however, that ef-

ficiency increased with both types of appliances during the two-week testing period.

R. S. Manly and Paul Vinton studied the chewing efficiency of twenty denture wearers. The function tests included effective occlusal area, maximum force, and sixteen performance tests with two test foods. They found that lateral movement in chewing was about the same for all test patients, but failed to state how this was measured. They conclude that denture stability is important to the efficiency of chewing and that with poor function the patient swallows larger particles. They feel that tooth form and degree of ridge development are other major factors.

Felix A. French states that tooth alignment to conform to the arch form and labial surface contour are more important than the outline form of the teeth in the production of esthetic dentures. He emphasizes the importance of pre-extraction records and of observation of teeth of blood relatives as aids in tooth selection and arrangement. He makes several valuable suggestions for pleasing esthetic effects by tooth modification and carving of the base material.

Frank A. Eich describes, in detail, a technique for making a permanent metal mold for custom-made acrylic teeth. The advantage of the procedure is the unlimited possibility for variations in color placement, stains, and so forth to copy the colors of the patient's teeth. This procedure makes the introduction of aging characteristics much simpler.

Joseph S. Landa presents a new and important approach to the problem of diagnosis of temporomandibular joint disturbances. He criticizes the common practices used in temporomandibular roentgenography in that the exposures are made without adequate knowledge of the jaw position. He suggests an excellent technique which can produce uniform results for diagnostic purposes. He then relates the roentgenographic interpretation to clinical findings.

Eugene T. McDonald explains the physiology of speech production, particularly as it applies to cleft palate patients. This is very timely and should be of great assistance to those who make prosthetic restorations for cleft palate patients. He outlines the requirements of a cleft palate prosthesis from the viewpoint of the speech pathologist.

—Carl O. Boucher

IMMEDIATE RESTORATIONS BY COMPLETE DENTURES

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THE subject of immediate restorations is not a new one, but it is one which commands much interest and is a phase of prosthetic dentistry which has great possibilities. There are still those who feel that the teeth should be extracted and the mouth allowed to heal before dentures are ever constructed. With these I do not agree, for I am convinced that the finest denture service that can be rendered is to take the impressions before any of the anterior teeth are lost and have the new dentures completed before the teeth are extracted. Many of our most satisfactory cases have been constructed as immediate restorations. This service need not be out of the financial reach of the average denture patient. There are some who do not believe in immediate restorations. However, they are overlooking one of the greatest practice builders they ever had a chance to use in their offices. When you can construct a set of dentures that look so natural that the patient's friends and relatives are not aware that he has had his teeth out, you may be very sure that that patient is going to be enthusiastic about you and your work. Those of you who are doing this need no encouragement, I know, for when you have a technique that gets results you are bound to realize its value. There are three groups of dentists: those who never make immediate restorations, those who occasionally do, and those who always make immediate restorations, when patients present themselves with the anterior teeth still in place. I do not need to convince this last group of the value of immediate restoration. However, there may be a few points which I will show that might be added to their present technique to advantage. I would like to convince the first and second groups of the value of this service and show them that it is not a difficult procedure.

Most prosthodontists and oral surgeons realize the importance of pre-extraction records. When patients' teeth must be removed, many of them go to the oral surgeon first and later decide who will make their dentures. This is going at it backwards. If a patient is referred to the oral surgeon by another dentist, it rather puts him on the spot, but he might suggest to the patient that he inquire of his dentist whether he has taken an impression of his teeth so that new ones can be made like his own. If this is done at the patient's request, it is better than for the oral surgeon to suggest to the other dentist what he should do. Dentists should be educated to the importance of pre-extraction records, and the public should be taught to realize that immediate denture service is beyond the experimental stage. It is a proved success and is the ideal method for construction of a patient's first dentures. It has every advantage and few disadvantages. Of

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course, in the beginning, immediate dentures serve only an esthetic function and should be used but little for chewing, but neither can the gums be used for chewing, and they serve no esthetic function. It is a sad situation when the teeth are extracted and all records are lost, and it is left to the prosthodontist to guess just what the patient's teeth looked like before they were removed. We may be able to construct dentures that look fairly well, but never are we able to guess the exact size, shade, shape, and arrangement of the patient's own teeth. The prosthodontist should be selected before the exodontia is done, and oral surgeons can be of great service to their patients if they will explain this to them. However, if the patient does not have a dentist in mind for this service, the oral surgeon can ethically refer this patient to some man who will give that patient a good denture service. Advisedly, I say denture service rather than a good set of teeth, for denture service is what the patients are paying for. A good set of teeth, if not followed up by the proper service, will be of little or no value a year or two from the time it is constructed, for the mouth will undergo changes which will need correction. That is why denture patients often drift from one dentist to another. The first dentist constructs the dentures, collects the fee, and says goodbye without explaining that his services will be needed later. Misunderstanding develops as a result of lack of explanation, and many men who could have a good prosthetic practice lose it because they are too anxious to collect that first fee and do not wish to be bothered with the follow-up service which is so important and which keeps their patients tied to their offices. There should be a close cooperation between the prosthodontist and the oral surgeon. I always accompany my immediate denture patients to the exodontist's office and place the dentures in the patients' mouths while they are under the anesthetic. Except in cases where it is contraindicated, I prefer to have the patient take a general anesthetic when the anterior teeth are removed. This, of course, could not be done in your own office unless an anesthetist were employed. I realize that the average practitioner, except in the larger centers, must necessarily do all types of dentistry. He must be the oral surgeon, the periodontist, the orthodontist, the prosthodontist, the crown and bridge specialist, and the operative dentist all in one. The large majority of dentists throughout the entire world fall into this class, and it places a big responsibility upon them to keep up in every phase of dentistry. The business of earning a living keeps a man so busy it is difficult to take time out to learn new techniques. However, it is to the general practitioner that I want to direct this paper in particular, and much credit is due him for the splendid way in which he carries out such a diversified practice. To the general practitioner goes the same honor as to the general physician who delivers babies, sets broken bones, performs major operations, and takes care of the health of the entire family.

The technique given here is one which can be used without difficulty and is one which will produce good results. There are many complicated techniques for immediate restorations. Many men make so-called temporary dentures followed later on by their so-called permanent dentures. This we do not do. We make no temporary dentures whatsoever.

If a patient can afford more than one set of dentures, we construct duplicate dentures, either at the time the original dentures are made or at the time of the rebasing of the immediate dentures, which is done six weeks after their insertion (Fig. 1). The duplicate denture is usually identical to the immediate restoration, but, unless the patient needs and can afford duplicate dentures, it is not necessary to construct more than one set of dentures. No dentures are permanent regardless of how long after extraction they are made. As long as patients wear dentures, these will need refitting because the mouth changes as the patient gets older. These changes are beyond our control, but they can be corrected by relining or transferring, and it does not necessitate the construction of new dentures unless the patient so desires.

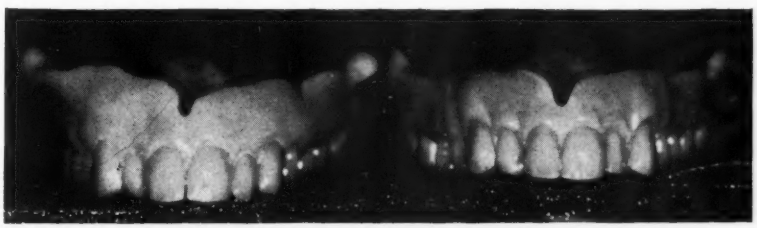

Fig. 1.—Duplicate upper dentures.

PRE-EXTRACTION RECORDS

At the first appointment with the immediate denture patient, a complete set of radiographs should be taken and impressions for good study casts made. These impressions are usually made with one of the alginates. At this first appointment we do not quote the patient a fee, but discuss the problems involved in the case. We give him another appointment and tell him that at this appointment we will have a report on the radiographs and study casts and that it will be possible at that time to outline the case and quote a definite fee for the work.

The following procedure and technique is not given with the idea that it is the only technique or the best, but it is simply the one that I use in my own practice, and it has proved to be the most satisfactory in my hands. I hope there will be some parts of it that will be of value to you if it is not used in its entirety. In most of our particular cases, we make color photographs of the patient before and after, and these have proved to be valuable records (Fig. 2). Our pre-extraction records consist of roentgenograms, study casts, and colored photographs of the patient. We use either an alginate or a hydrocolloid for the impressions. It is not necessary to use a complicated impression technique at this time as rebasing will be necessary later. Then very accurate impressions are made for completion of the case. At first, I used nothing but the hydrocolloids and did not trust the alginates except for study casts. However, the alginates have proved themselves to be accurate and will make good impressions for this purpose. I have been unable to see any practical difference in the end result by using either of these materials. If care is used in watching the con-

sistency of the alginate, it can be placed in the mouth at a time when it has body enough to force it up into the buccal and labial folds and get a good impression of these areas. We never make immediate restorations of all the teeth, nor do we advocate the extraction of all the teeth at once. The extraction of too many teeth at one time is dangerous to the patient's health, and the restoration would be too painful to wear. The posterior teeth should be removed at least a month before the impressions are made. All soreness should be gone from the gums, and they should be healed. Only the anterior teeth are extracted at the time of the insertion of the immediate restoration. By doing it this way, patients are able to wear the new dentures with very little discomfort, though they should not expect to exert pressure on the dentures until the soreness has left the ridges, new bone has formed in the sockets, and the tissues have built up a resistance to pressure. This usually takes at least six weeks, and in the meantime, the dentures are worn for appearance. This is certainly more to be desired than going edentulous. Often the patient will make considerable use of the dentures, depending upon how long the posterior teeth have been out. It takes a year to build a good ridge.

Fig. 2.—Pre-extraction records.

I always explain to my patients that there is no charge for the first rebase which is done at six weeks or as long after that time as they wish it. The longer they wait for it, the longer it will last before they will need another. I impress upon them that the first one is free, but that as long as they wear dentures they will need this service, and I tell them what the charge will be when it is necessary to have it done. Patients are likely to try to shift the responsibility for this upon us and expect us to service their dentures the rest of their lives for nothing. We should not sell dentures. We should sell denture service, for without it the dentures are not going to be satisfactory forever. If the patients do not understand this, in their opinion we will be at fault, and our dentures will be unsatisfactory. Let them understand that their mouths will be continually changing as long as they wear dentures.

IMPRESSIONS

As the impression is pressed to place, the cheeks should be lifted out to prevent trapping of air around the periphery and then pressed down so that the borders of the impression will not be too thick. An alginate impression should always be placed in potassium sulfate solution for from ten to twenty minutes before the casts are poured. If this is done, the surface of the casts will not be softened by the alginate material. If hydrocolloid is used, it should be poured immediately after the impression is taken. If it is not poured immediately, it should be placed in a closed jar in which there is cotton that is saturated with water. This prevents the moisture content in the hydrocolloid from evaporating, and the hydrocolloid does not take up additional moisture as it would if placed in a water bath or solution.

TOOTH SELECTION

The selection of teeth is very important in immediate denture work, and it is well to study this at the first working appointment. Since in our immediate dentures we reproduce exactly, with minor corrections, the tooth form, color, shape, and arrangement of the patient's teeth, it is necessary that we be able to make an accurate substitute if the result is to be what we anticipate. We use both porcelain and plastic teeth for this work, for many times the proper mold or shade is only available in one or the other. The tooth form will often have to be modified whether we are using porcelain or plastic, and it is rarely possible to select a set of six anteriors and be able to use them as an entire set. Frequently, it is necessary to select centrals from one set, laterals from another, and cuspids from another and then modify the form of each of these. This takes us back to our tooth carving days in dental college, and to get the best results we must refer again to that same technique. The use of a millimeter gauge is very important, and the tooth should be duplicated in all dimensions, width at the incisal edge, width at the gingiva, length from the gingiva to the incisal edge, mesial and distal contour, and labial contour. We are actually giving the patients hand-carved teeth in duplication of their own. Many teeth will require characterizing or staining, and this should be done before a super glaze is added and the tooth is fired in the porcelain furnace (Fig. 3). Some of the newer porcelains may be shaped and polished, and glazing is not necessary. If baking is to be done, we usually prefer to use a tooth without pins, and if gold pin teeth are used, the temperature of the porcelain oven must be kept very low or the pins will become loosened and cause failure in the denture later (Fig. 4). Platinum pin teeth are ideal for this purpose, but they are difficult to secure and usually have to be obtained on special order from the factory. While porcelain is more permanent material than present-day plastics, it has the disadvantages of being quite brittle and easily broken; when special teeth are made, they are more difficult to replace. It is for these reasons that the new plastic teeth have become so popular for use with immediate restorations. Before advocating their use, I want to give a word of caution with regard to them. If you have used them at all, you have probably seen some cases return with the surface of the anterior teeth crazed or checked. This is more easily seen by

Fig. 3.

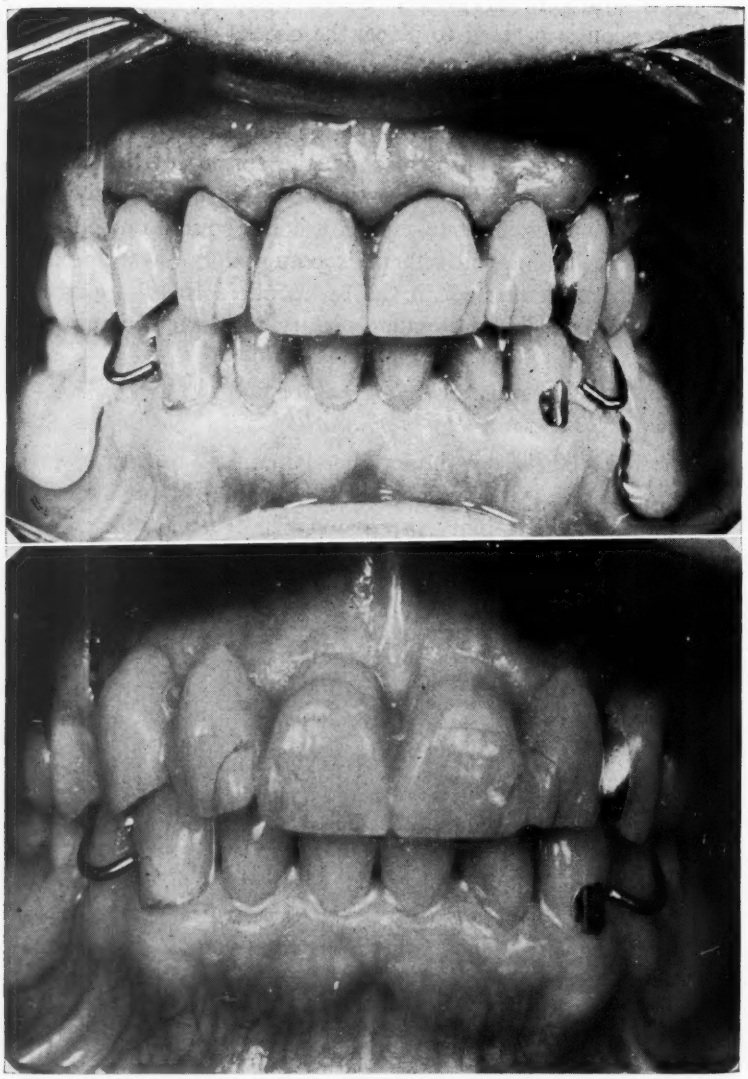

Fig. 4.

Fig. 3.—Immediate upper denture immediately after insertion.

Fig. 4.—Same immediate upper denture six weeks after insertion.

transillumination, but it becomes very apparent when the dentures are dry. There are two precautions to be taken to prevent checking and crazing: (1) In setting up the teeth and waxing the case, it is important that the surface of the teeth never be flamed. It is dangerous to use a flame on the wax around the necks of the teeth, for this will cause the teeth to craze. It is better to carve the wax and polish it. (2) Solvents are contraindicated and should never be used around plastic teeth. Chloroform, acetone, carbon tetrachloride, and alcohol should never be used on the wax or in the flask with plastic teeth. When the flask has been

separated and the wax removed, the teeth should be thoroughly cleaned with hot water by pouring a small stream of water into the flask. Never place the flask in boiling water. The remainder of the wax is then removed with a solution of equal parts of kerosene and ether. This solution will not affect the teeth and will not cause them to craze. The use of either chloroform or carbon tetrachloride definitely will cause plastic teeth to craze. The manufacturers claim that the newer teeth, if handled with these precautions, will give very satisfactory results, and the unfavorable results which have occurred in the past will be avoided. There certainly are many advantages in the use of plastic anterior teeth. It is easy to carve and shape each individual tooth to its proper dimension and contour with stones. A beautiful job of recarving and polishing can be done in a very short time, and it makes a great difference in the appearance of the immediate restoration. Plastic stains are also available so that characterizing can be done on these teeth just as well as on porcelain teeth. I have been very slow to accept plastic teeth and have used very few of them for posterior teeth. However, they are most valuable in short bite cases. They do have an advantage in that there is very little noise when the teeth contact, and they do eliminate the clicking sound which is often heard with porcelain teeth. Personally, I prefer to be conservative and use them only on selected cases, where they can be kept under observation. In the majority of our cases we still prefer to use porcelain teeth throughout.

The shaping of the anterior teeth should be a chair operation. I usually shape the centrals, laterals, and cuspids at the chair, comparing the teeth with the natural ones, rather than with the stone teeth. In this way, they are easier to duplicate, and it gives the patient an opportunity to observe the painstaking detail that is required to reproduce his own natural tooth effects. Exact duplication is not always desirable, and improvement can often be made, but these decisions can best be made when the patient is present.

JAW RELATION RECORDS

At the second appointment, we usually determine the vertical opening and the approximate centric relation. Baseplate material is adapted to the cast and accurately fitted by the use of tin foil and zinc oxide-eugenol paste. To these baseplates are added wax rims. Centric closure is obtained without displacement of the ridges. You will find that if the patient exerts pressure upon the occlusion rims while centric relation is being recorded for an immediate restoration when all the posteriors are missing, the anterior teeth will be held apart when the casts are mounted. It is important to have the recording wax very soft. This can best be done by keying the upper wax rim and pooling the wax on the lower rim with a wax pooling instrument. The patient is instructed to close until the teeth contact. If a vertical stop has been maintained, the wax should be soft enough that no pressure is exerted on the ridges when the remaining teeth touch. This operation should be repeated until this is accomplished. The casts are now mounted on the articulator, and check bite plates are mounted on the bases with white compound after the wax rims have been removed.

At the next appointment the plaster check bites are taken (Fig. 5). Denture powder is placed in the bases to stabilize them while this is done. After a Gothic arch tracing has been completed, centric, protrusive, and right and left check bites are taken in plaster. If the articulator is not fully adjustable, only centric and protrusive check bites should be taken, and, if the instrument to be used is nonadjustable, only a centric check bite is taken. It is very important

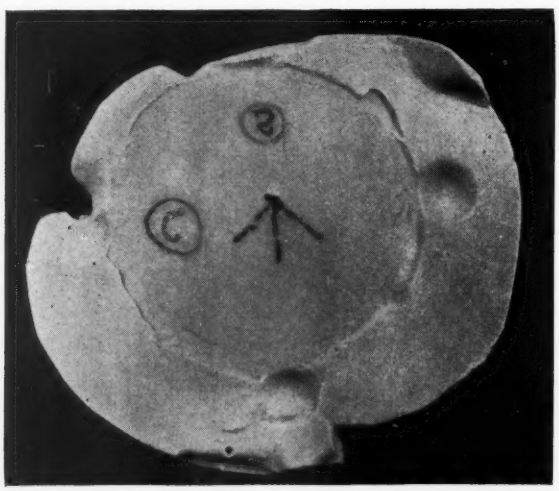

Fig. 5.—Plaster check bite used for setting the articulator.

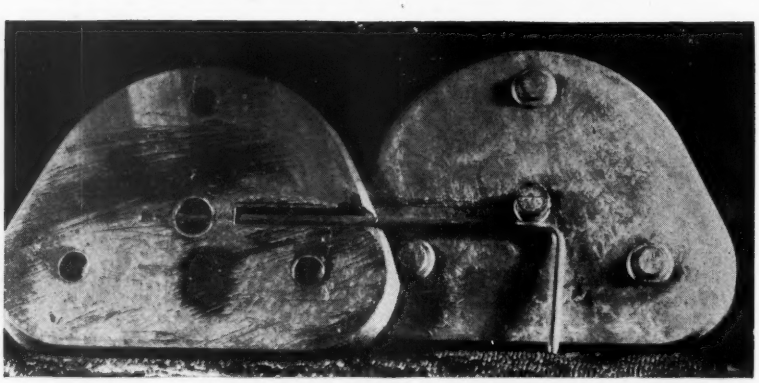

Fig. 6.—Metal split-cast plates designed by the author used for remounting casts on the articulator.

that correct centric relation be secured. The eccentric check bites are of value only if an adjustable instrument is used. Centric relation is at the apex of the Gothic arch, which represents that most comfortable retruded position of the heads of the condyles from which lateral movements can be made at a given vertical opening. If there is an interference with the teeth in making the Gothic arch, the central-bearing screw will have to be raised to clear these teeth. The casts are mounted on the articulator by some split-cast method (Fig. 6).

ANTERIOR TOOTH ARRANGEMENT

A Carborundum disc is used to make a slice through the stone tooth that is to be removed, being careful not to touch the contact with the adjoining tooth (Fig. 7). This is done also on the opposite side of this tooth, and then a cut is made through the center of the tooth (Fig. 8). These two pieces are fractured out with an instrument. Then a round vulcanite bur, about the diameter of the

Fig. 7.

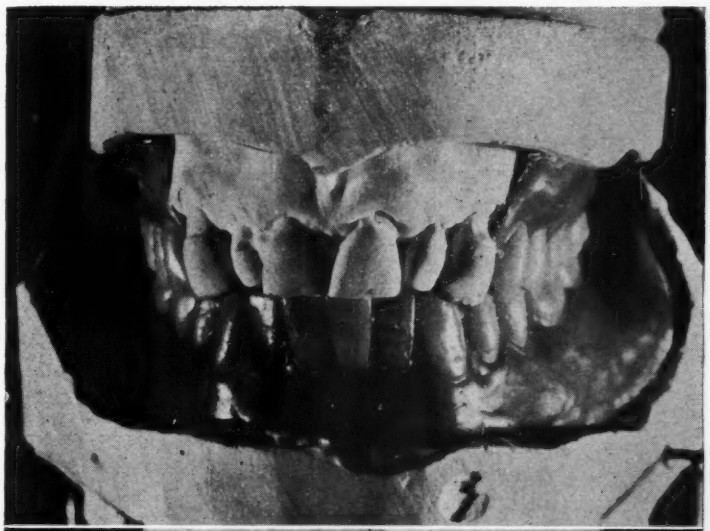

Fig. 8.

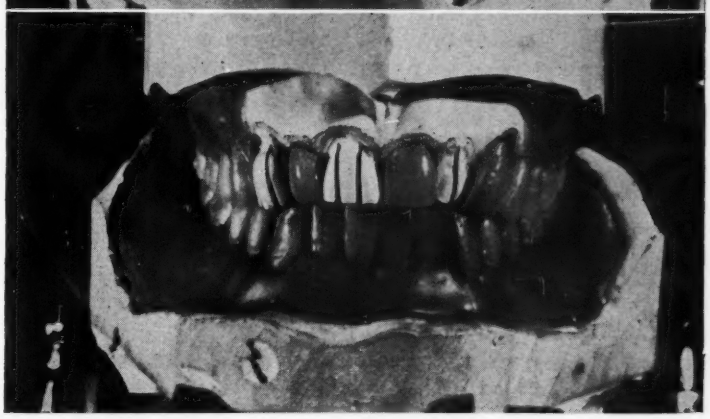

Fig. 7.—Cast for an immediate upper denture mounted against a complete lower denture.

Fig. 8.—Duplicating the shapes and positions of the natural teeth.

tooth root, is used to prepare a shallow socket, the position of the socket of that tooth having been visualized. This will give space to set the neck of the tooth in direct relation to the free margin of the gum on the cast. The projections of acrylic on the inside of the dentures which result from these sockets in the cast will be ground out after the dentures have been processed, and the inner surface will be smooth. We do not follow the common procedure of putting a labial

flange on our immediate restorations immediately. We often follow the technique of setting the teeth in the sockets with the natural gum surrounding them. This gives a most natural effect if none of the labial plate is lost. We do not remove any of the labial plate, as we wish to preserve as much of the ridge as possible. Within six weeks, there will be shrinkage sufficient to allow for a labial flange, and the labial plate of bone, which is so valuable, will not have been lost (Fig. 9). We trim the labial surface of the cast but slightly.

Fig. 9.

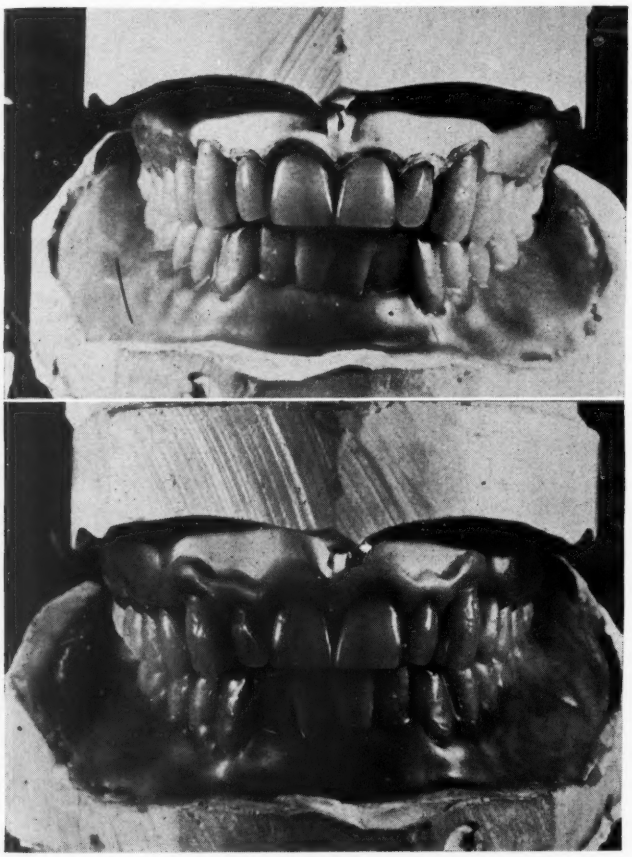

Fig. 10.

Fig. 9.—Showing all the teeth in position.

Fig. 10.—Waxing completed ready for flasking.

DUPLICATION OF GUM CONTOUR

The following method of duplicating the patient's own natural gum contour does not distort the lips by placing a labial flange at the time of the immediate insertion (Fig. 10). When the teeth are all set up, that part of the cast which duplicates the gingival tissue has not been disturbed, but the artificial teeth are projecting from the gingival tissue of the cast in the same relation as the natural teeth do in the mouth. This is very important because it requires not only the

reproduction of the teeth, but the reproduction of those soft tissues around the teeth to make an immediate restoration look natural. The immediate restoration, when finished and placed in the mouth, does not have a labial flange extending up to the reflection. It does have the interseptal tissue and that tissue immediately above the necks of the teeth reproduced in plastic. The flange is thinned out to a knife edge about halfway up the labial surface. In this way, the patient looks natural on the very first day. Since no tissue has been lost higher up on the labial surface of the ridge, the placing of plastic material in this area would distort the upper lip and spoil the esthetics of the case. Within a period of six weeks, we find there has been shrinkage enough to allow for the thickness of a labial flange; in fact, in most cases it is required to prevent the upper lip from sinking in. I can remember only one case that I have made this way where there was no shrinkage across the labial surface of the ridge from cuspid to cuspid, and that patient is still wearing a denture with no labial flange. However, if we do not place a narrow, thin flange above the teeth, a few weeks following surgery,

Fig. 11.—Balanced occlusion is imperative.

spaces will begin to develop, and the gum tissue will resorb, exposing the necks of the artificial teeth, and the gingival region will become quite unsightly. For this reason, we modified our technique to replace the interseptal tissue and a margin of the gum tissue. Before flasking, a very thin layer of wax is flowed over the labial surface of the cast and is carved down until it is only paper thin. It should extend from 5 to 10 mm. above the neck of each tooth. The space for this flange is obtained by trimming the cast above the necks of the teeth when the case is in the flask, not by adding wax on the surface of the cast. The front of the denture being left open in this manner allows the tooth sockets to have free drainage, and if there should be any swelling, it will not be confined. This is a compromise between the use of no flange and a complete flange and has many of the advantages of both and eliminates the disadvantages of both. The gums will shrink as we know. It must be explained to the patient that though the dentures seem quite firm when he starts wearing them, they will gradually become looser during the six-week period before they are to be refitted. The fee quoted to the

Fig. 12.—Patient with natural teeth (before).

Fig. 13.—Patient with immediate restoration (after).

patient for this service includes the placement of the immediate restoration, the treatment visits during the first six-week period, and the first refitting and transfer of the dentures. We know there will be changes beyond this period, and for as long as the patient wears dentures. Our original fee includes only the one free refitting. From then on when the dentures need this service, it is the patient's responsibility. This should be carefully explained to the patient so that

we are not blamed for changes which are beyond our control. If the dentures loosen during this six-week period, we have the patient use one of the adhesive powders to keep them in place until the new base and labial flange are placed on the dentures. They can be assured that after this is done there will be no more need for the powder.

The same post damming technique is used in immediate restorations as in the complete denture technique. It is done entirely on the casts by the means of a No. 8 round bur. Well-balanced dentures can be made just as well for immediate restorations as for a healed mouth. There is no reason for making temporary dentures which do not embody all the precision which we require in our best denture technique. Why build an inferior restoration to start the patient's denture-wearing experience? It is better to give the patient everything possible in the beginning, and then by transferring, it can be preserved. This same denture can continue to serve indefinitely. The patient should be educated to the fact that his mouth is continually changing, and that everyone wearing dentures will reach a period when his dentures should be refitted or transferred.

After the dentures are cured, they are again remounted on the articulator. Selective spot-grinding and milling are done before they are removed from the casts and polished ready for the patient.

It is important that all dentures be checked carefully with articulating paper and all lateral stresses removed. Remember that there should be an even contact in centric position, and that there should be at least three-point contact in all positions (Fig. 11). The rule to follow in adjusting the occlusion is: grind the buccal cusps of the uppers and the lingual cusps of the lowers. If there is interference on the balancing side, it should be eliminated on either the upper or the lower tooth, as indicated. The length of time that dentures will remain firm is largely determined by the freedom with which those dentures glide without interference when no food is present in the mouth. A balanced occlusion is more important for this reason than for efficiency in chewing the food. Permanence of the fit and comfort for the patient are factors which should be built into every denture, and this is done by balancing those dentures on an articulator or carefully correcting the occlusion in the mouth.

Those patients who are wearing dentures that are not detectable are principally those patients who have had immediate restorations. There is no reason why function in immediate restorations should not be equivalent to that built into any other denture, and the esthetics is usually far superior. Dentistry has been blamed by the public for its poor reproduction of natural teeth. All patients dread the day when they are to lose their teeth, principally because of the fear of looking like so many who are wearing dentures that are so obviously artificial. We are judged more by the esthetics of our work than we are by its function, though neither should be sacrificed. Each set of dentures which we construct should be an exhibit to our patients and to the world of our skill and ability to reproduce the best in nature (Figs. 12 and 13).

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SOIL, HEALTH, AND THE DENTAL PROFESSION

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IT IS my thesis in this paper that there is a close relationship between the quality of the soil and the quality and quantity of the food that can be produced on that soil. Unless we are careful, such statements can lead to unnecessary controversies. It is generally agreed, nevertheless, that soils that have lost, or have never possessed, adequate fertility are restricted in the types of crops that they can produce, in the total yield of those crops, and often in the health of those crops, and in consequence the health of animals that live off of that land is affected.

It follows, then, that the proper application of the principles of soil and water conservation, when taken together with a balanced rotation of the crops suitable for the land, will greatly increase the yield of forage and grains with all of the essential elements for animal growth and health. These improved food sources will then help to insure that more people have an adequate diet. We know also that when people do have an adequate diet they have little or no sickness. It follows then that when animals or people get an adequate diet they tend to throw off or resist infectious diseases. With an optimal diet health, contentment, and longevity are likewise increased.

In these facts lies a challenge to all who are interested in the health of our citizens. To those scientists who have been trained to think in terms of the *total* population, it is a challenge for them to step up the tempo of their researches lest we all be dead a long time before they dare to speak of their results. To you and me, who have been trained to think of both health and disease in terms of the *individual*—your patient and yourself—me and mine—it points to the fact that we have greater assurance that chronic illness can often be overcome by improvements in the nutrition of the individual victim if we work within the framework of what is within "the norm" for human beings (not normal, not average, not usual).

So what the people throughout the world need, including us here in the United States, is *more* good food, and to get it we must focus our attention upon the capacity of our soil to produce foodstuffs. There have been misunderstandings about soil-health relationships, but these arise, let me emphasize, not from the facts, but from the manner of emphasis and interpretations put upon those facts.

The phenomenal decline in the death rate of the American people since the development of bacteriology is evidence of a great improvement in their health. It is not to be taken, however, as evidence of any great improvement in their resistance to disease. For the most part, this enviable record has been the result of conquering some of the more outstanding of the unfavorable environmental factors

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which man in the past has not been able to withstand. The most credit must go to that smart man who conceived the idea of putting the toilet in a warm room and connecting it with a sewer and to the sanitary measures with which the engineers were able to follow the plumber. Next in importance have been developments in the field of refrigeration which have proved so valuable to our children and infants, in that milk is not only pasteurized but is kept cool at all times until it is delivered to the very lips of the children. So the plumber and the ice man should be given almost all of the credit for the great expansion of our life's span in the last seventy-five years.

Our medical historians believe, and they are supported by the paleopathologists, that disease must be old as life itself. As certain as it is that the human organism is able to adapt itself to a great variety of outside influences, nevertheless it is also evident that at times its capacity to make such adaptations is exceeded by the stresses and strains inherent in living. There can be no doubt that at all times there must have been a great variety of factors—some favorable, some unfavorable—some physical, some chemical, and some biologic—acting upon each man and woman since the beginning of the race. When the impact of any or all of these factors added together exceeded the adaptability of the particular individual with his peculiar inheritance, present nutritional state, and capacity to resist parasitism—insects, worms, animalcules, molds, and bacteria—his or her reaction would no longer be within the norm. These pathologic reactions would produce what would then appear as the symptoms of disease.

It is well with the natural order for plants to live on one another or for animals to live on plants and for one animal to fall prey to another. So, as Moodie[1] has pointed out, "it seems very likely that the phenomena of parasitism is very much older than man himself." In addition to parasitism, man has been subjected to accidents and to the premature wearing out of one tissue or organ of the body.

Lightning, drowning, hurricanes, starvation, and accidents of all kinds, including those of combat, must have plagued man from the beginning. So also did his failures to adapt himself successfully to either the immediate or long-range exposures as he migrated over the tropics, into the arctic, from sea level to the highest mountain. All of these physical factors tested severely and often fatally the ability of man's organism to make the adaptations necessary for survival.

Living has always been an adventure to the individual man, and with it has come nervous apprehension and tension. So since the beginning, the biologic stimuli of great importance have been those bodily changes in response to rage, fear, and the other emotions.

Man's concept of disease and its causes has followed the long, slow, and often painful steps of his other evolutions. Primitive man, of necessity seeking some explanation for his mysterious aches and weaknesses, found solace in ascribing his symptoms to supernatural influences. *From that day to this, man has absolved himself of any responsibility for his own sickness.*

First, it was the demons who were to blame. Medicine men were called upon to drive these devils out of the victim's body. (We still see a remnant of this

superstition in the rush to take a cathartic at the first sign of sickness.) Later, demonology was replaced by the idea of divine wrath as the cause of all sickness.

A long time after this, man became aware that his physical surroundings had something to do with the development and spread of epidemics. He began to advance theories about "miasmas," "vapors," and "humors" as the causes of disease. Glimmerings of the concept of contagion and infections began to be seen in the Middle Ages, and it glowed brighter and brighter. The development of the microscope and the knowledge of the structural changes in the bodies of men who had died of disease fanned it, and it then burst into a blinding flame with the discovery of Pasteur and the consequent birth of the science of bacteriology.

By the hope that a specific germ might be found to be the cause of each and every disease, the scientists were spurred on to a whole series of brilliant discoveries. One after another the germs were identified as the specific causes of infectious diseases until the list of available diseases was pretty well exhausted.

At the same time, the science of immunology developed alongside of bacteriology, and man began to learn about his own resistance to disease.

Finally, it was learned only recently that micro-organisms of one sort or another do not cause all disease, and even when they are the immediate cause of a specific disease, they are not the ultimate cause. In addition to the pathogenicity and virulency of the germ, the inheritance, the nutritional state, and the functional capacity of the catalytic systems to produce the immunologic reaction of the man to be invaded must always be taken into account. For more than seventy years (1870-1940) our students of disease, as well as we dentists and physicians, were blinded by the concept of the specificity of disease-producing germs to the point where we could not see that dis-ease only follows a *virulent* germ that breaks down the resistance of a *vulnerable* host. In the last few years our minds are turning back to teachings of the ancients; these teachings are now reassembling and developing into the subject of social pathology and the ecology of health.

We must get a truer concept of disease and health. Dis-ease is the unfavorable effect produced when, for some reason, the totality of a human body fails to adapt itself to its surroundings. Human beings vary a great deal in their ability to adjust themselves to the various unfavorable stresses and strains which their environment is constantly imposing upon them. We must grasp the concept that disease results when the sum total of the forces of resistance in the human being is broken down by the sum total of these stresses and strains in man's surroundings.

If we thus approach the subject of disease from the ecologic viewpoint, we shall be on some much sounder ground than if we use the conventional approach and emphasize the immediate rather than the ultimate cause. From this viewpoint, disease is the result of a breakdown on the part of the total individual. The unfavorable factors which caused him to break down may be grouped as:

1. Physical agents, such as cold, heat, barometric pressure, light, electricity, radioactive substances, weather, and climate
2. Chemical agents, such as foodstuffs, minerals, bacterial protein, toxins, allergens, and so forth
3. Psychologic stresses, much overemphasized today.

On the other hand, the totality of the individual is the sum total of three groups of factors. These are:

1. Genetic factors, by which he has inherited a predisposition toward certain afflictions or an unusual capacity to resist certain unfavorable factors
2. His nutritional state, by which the integrity of every cell in his body and its functional capacity are assured or jeopardized
3. His catalytic systems, by which his cells are able to use or to reject materials from the outside through the use of hormones, enzymes and coenzymes, antibodies, vitamins and vitagens, and other catalysts.

Now one can visualize, for instance, how changes in the weather, harmless chemicals like dog hair, and emotional strains may produce disease through the summation of strains that are greater than the individual can bear. We see how physical agents, chemical agents, and psychic trauma may break down the individual's power of adaptation. Or again we can see how an inherited predisposition, bad nutrition, a hyperactive catalytic system, or the lack of one, may cause the breakdown we call *disease*.

RESISTANCE TO INFECTIONS

It has always been an attractive belief that good diet makes one better able to resist infections and related diseases and conversely that a faulty diet makes one more susceptible to such disorders. What could be more reasonable than this? An adequate intake of all essential nutrients certainly must be necessary for the individual cells to perform their several functions. Thereby growth is promoted, the adult is maintained in good health, and the degenerative processes of old age are delayed. At all times the body is kept in fighting trim to resist and combat bacteria and other noxious influences. The truth of these general tenets, if not actually stated, is implied in most of the statements by nutritionists concerning the importance for health of good food and consequently of good nutrition. But let us not forget that such general statements about the role of nutrition do require qualifications of one kind or another. These qualifications must be made because we must take into consideration the inherited background of both the human being and the bacterium, virus, or parasite that is about to invade the body of that particular human being. H. A. Schneider[2] has investigated this problem at the Rockefeller Institute, using mice for his experiments. The host—a human being, if we may transfer his results to human beings—can have an inherited resistance to the threatening invader or an inherited susceptibility, or he may be, as we all usually are, random bred and thus have a nonselected inheritance and not be too resistant or too susceptible to the threatening germ or other pathogenic parasite.

It is in this group of individuals who have come from a random breeding that diet plays a major role under certain conditions in determining whether we get infected, and by what, and under what conditions (Fig. 1). But, at the same

time, let us not forget that the germ or parasite has something to say about this invasion, and it too is a victim of its own inheritance and nutrition. It may have a high degree of virulency or a uniformly low virulency, or its inheritance may have given it a mixture of virulency or a lack of it. As can readily be seen, there are nine different ways in which the three broad classifications of hosts could interact with the three broad classifications of invaders. Now Schneider found that in only one of these situations did diet have a determining part, and that was when an organism of random breeding with no great susceptibility or resistance was invaded by an organism which, too, was not cursed with a high degree of virulence or

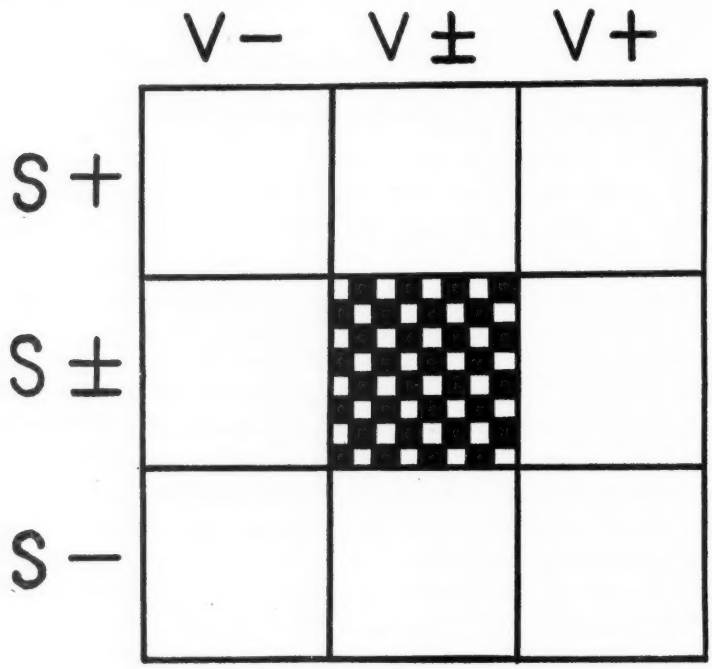

Fig. 1.—In setting up experiments with animals that have no susceptibility (*S*—), animals that have run-of-the-mine susceptibility (*S*±), and animals that are markedly susceptible (*S*+) with a germ which may be in different cultures very virulent (*V*+), have a run-of-the-street degree of virulency (*V*±), or possess practically no virulency at all (*V*—), we created nine situations in which nutrition (food) plays a determining part in only one. That is, where random-mated animals are invaded by ordinary, run-of-the street germs.

gifted with a low degree of virulence. In all of the other eight types of the infection model, diet had no effect upon the progress of the invasion. As the author states: "Although the dietary effect is thus restricted to a single model, it does not follow that this is a restriction on the significance of such dietary effects for natural infections. On the contrary, in the natural world it is just these elements of nonselective breeding which undoubtedly occur with the greatest frequency. But more often than not, the other eight types of situations are the experience of the classical laboratory infections. Hence, too frequently the results of the laboratory

investigation of the effects of diet upon the progress and spread of infections cannot be applied to our human world. In other words, it is precisely that nutritional forces are important in determining the outcome of infections, and the attempts to study these affairs in the laboratory demand a kind of experimentation which is ordinarily not practiced."

It should be clear now why Friends of the Land have had a deep interest in these investigations. We are concerned with the use to which our soil is put to the end that every foot of it will be treated according to its need and be used according to its capabilities, so that we will have a permanent type of agriculture insuring all of the people all of the food they will need. This projects our interest at once into the crops that grow on that land, for our objective is the wise use of resources to the end that man may be served now and through the ages to come. Our major concern then becomes the relationship of human health and behavior to the soil from which all mankind draws its sustenance.

I feel that the concept of specific entities and specific causes has been overworked. Behind every one of them is *malnutrition*. The great killers today overlap. Each case differs in details from every other one. What we are today is *the result* of what happened yesterday. Among the details of our life history, however, nothing else is so important as what our grandparents, our parents, and we ourselves have had to eat.

The wider appreciation of the concept of the fundamental mechanism of adjustment to environment and the disease that results when it fails would go far toward improving the health of our people. It makes of health a personal responsibility. The greater individualization which this concept imposes in the analysis of causes involved in a particular diseased person would go far to improve medical practice. This type of individualization of the problems of sickness can never work in a large clinic, be it private, university, or governmental. Patients cannot be numbers under such a plan. This type of evaluation of sickness can only come about when an alert physician takes personal and confidential interest in a cooperative patient. Effective treatment, creative, preventive and curative, however, will always depend upon the elimination or the control of all of these multiple causative factors of disease of which malnutrition is most fundamental and, therefore, the most important.

These are the reasons why we of Friends of the Land have become interested in nutrition and its relation to the soil; why also we have come to realize that fundamentally good nutrition must depend upon good food grown upon soil that is rich in all of the bioelements essential to the growth and repair of the tissues of the human body.

The prevention of dental decay and diseases of the soft tissues of the mouth is infinitely more important than the provision of dental care for persons who are losing their teeth.

The statement of the problem of dental care, however, is not as some people propose. It is not the problem of redistribution of dentists. Dentists, like physicians, settle and establish themselves where there is the most work to be done. As most of you know, the first 70,000 recruits for the United States Navy for the

last war were selected from men who had no infection of their gums or who had at least eighteen teeth without wide edentulous areas; if there were such areas, the men were provided with proper prosthetic appliances. Preliminary to his "boot" training the naval recruit was carefully examined by a competent dentist, and the results were tabulated and referred to the area in which the boy was born and reared. These areas were arranged in the same regions that the American Dental Association used in its survey. The average recruit was found to have 10 cavities, 5 fillings, 4.7 teeth missing, and 0.2 teeth needing extraction. There are many who believe that health can be provided by the dentist and the physician. I maintain that such is not the case. When the reports on these naval recruits were spread upon the maps of the United States on a regional basis, it was found that, contrary to what seemed to be expected, Texas and adjoining areas have the fewest dentists, next to the lowest per capita income, but the best teeth among our sailors. New England, wih a large number of dentists, dental colleges, and the second highest per capita income, had by far the worst teeth. When we showed this survey map to Dr. William A. Albrecht, head of the Department of Soils of the University of Missouri, he at once recognized that, in general, the condition of the teeth correlated with the fertility of the soils in that area.

Any discussion of the overrefinement of foodstuffs or of food-soil-health relationships can be molded very readily into a cult belief, according to an ancient medical formula of "one cause—one cure—one master—one book," the bible of the cult. At the other extreme we all recognize the necessary conservatism of the investigative scientists; none are more conservative than those who have to do with nutrition. I am not an investigative scientist. I am a practicing physician, one who applies science to the art of practice. You may rest assured, however, that I do not represent any cult.

Sears[8], the noted ecologist of Yale University, has recently pointed out that there are an increasing number of men with the background of a scientific discipline who are urging that the relationship between soil and health be given more consideration in our planning. These are Colonel R. McCarrison, Dr. G. T. Wrench, William A. Albrecht, Dr. L. J. Picton, Francis Pottinger, Jr., Dr. Allison G. James, Dr. Phillip Norman, and Professor John Detwiler, to mention only a few. Sears also emphasizes that these men are supported by leaders in agriculture with a great deal of practical experience, notably Louis Bromfield, Sir Albert Howard, Lady Balfour, and E. A. Faulkner. None of these can be indicted as cultists. Sears likens them to the advance guard of an army which is on the march to secure for mankind the best possible diet in the shortest possible time.

As such, they are not to be confused with the "wild men" who are native to this unexplored country. It is not surprising, however, that active soil-health cults have grown up around the fringe of this advance guard. The members of this advance guard recognize that there is still much that must be proved, and they also recognize as well that a sound line of established facts connects their position with that of the main body of citizens. It remains to consolidate the objectives by bringing up the main body of men and facts. This means filling in, through research, the gaps in our knowledge of these relationships and persuading the main

body of nutritionists, hygienists, and teachers to make use of every single bit of knowledge that is now available.

We who are interested in promoting longevity are most anxious that this be done and done promptly. Any contribution that a knowledge of nutrition and soil conservation is going to make to my life must be applied right now, or at least within the next three or four years. The job of getting ready for old age really begins on the day that your child specialist discharges you, for geriatrics begins when pediatrics ends. You and I, our children, and even our grandchildren are going to be dead for a long time before the investigative scientists are going to fill in many gaps that some of the more conservative insist must be filled in before we make any sort of move which is predicated on the existence of this relationship of health to soil fertility.

But as long as nothing is done that is out of line with all that we know about nature and as long as whatever is done is in line with all the knowledge which scientists have been able to assemble for us, we must be, in my opinion, on the right track to add years to life, and life to our years in strength, happiness, sound judgment, and mental alertness. In addition, we shall bequeath to our children a land whose fertility has been restored. Only in this way shall you and I be able to give a good final report of our stewardship.

At the time of founding, Friends of the Land issued a manifesto in which it phased this belief:

> "Evidence on this point is far from complete, but the trend of the accumulated findings is unmistakable. If the soil does not have the essential elements in it, plants that grow there do not; nor do animals that eat those plants; nor do the people throughout a country who eat those plants and animals. Soil debility soon removes the stiffening backbone, lowers the beat and vigor of the national blood stream, and leads to a devitalized society."

For ten consecutive years now I have had the privilege of arranging the program for the Annual Conference on Conservation, Nutrition, and Health, sponsored by Friends of the Land and offered on the campus of Ohio University at Athens, Ohio. There, under the stately elms planted long ago by Reverend William McGuffey, we have brought each year some fifteen authorities on the various phases of this relationship. Everything that these 140 distinguished scholars has told us fits into the framework of our manifesto. All that many outstanding students have been able to assemble from the literature also confirms the principle that:

> "Good health depends upon good nutrition; good nutrition depends upon good digestion, good muscular tone, and good food, but the greatest of these is good food; that while good food can be spoiled in the harvesting, processing, storing, cooking, or serving, its fundamental quality is determined by the quality of the soil in which it is grown. It may, therefore, be that all of these things have been attended to and the quality of the food still be poor because it lacks some element that is either directly or indirectly essential to our health."

We live on a thin layer of 9 to 12 inches of topsoil made from weathered rocks on their way down to the sea. Without soil nothing could live upon this planet except those beings that could subsist on food from the air or the sea. It is there-

fore imperative that agriculture produce for all of our citizens crops in adequate amounts to furnish, in proper form, the nutrients necessary for the feeding of the human body in the best possible way. Mere food is not enough. It is a balance of all of the essentials that is important. And all of these elements must come from the soil to man through the plants directly or through the plants to animals and then to man.

All plants and animals will strive desperately to adjust themselves to the lack of one or more of these elements. Often they succeed in living through a short life and in reproducing an inferior type of offspring, but in general there is biologic failure.

It is clear that, until more facts are gathered through research and their significance is properly assessed, it is rather hazardous to speculate regarding the full significance of the influence of soil fertility on human nutrition. We of Friends of the Land are, nevertheless, proud of the part we have had in creating public interest in the general problem as an introduction to a personal knowledge of the subject.

Enough interest has been created to insure that adequate research to clarify the problems will be supported. A good start has already been made. Such research requires the painstaking efforts of highly trained scientists, and some of it will have to wait for the advancement of our knowledge of fundamental physics and chemistry. It cannot be expected that we shall arrive at all of the answers in our lifetime, but we can hopefully look forward to a time 100 years or more in the future when the race shall have a correct appraisal of the place that fertilizers, composts, and native soil fertility have in human nutrition.

SOIL DESTRUCTION

The bulk of all plants and animals is supplied by air and water in the form of carbon, oxygen, hydrogen, and nitrogen. In man there is an additional 5 per cent composed of mineral elements coming from the soil. The smallness of their amount as found in plants and animals does not make them the less important.

Only in the last fifteen years have we begun to awaken to the danger that faces our nation through the destruction of our topsoil. The soil scientist who spends his life in its study sees the soil as the foundation of all human activity. He knows that certain soil gives rise to certain plants and to certain types of resultant civilizations. He knows, too, that a healthy, vigorous civilization demands a proper adjustment of man to the soil of that country.

The damage that has been done to our soil has been done by man who unleashed the winds and the rains. Water erosion occurs chiefly on sloping land and is the more apparent of the two, but wind erosion occurs on both level and sloping land. Much of the damage has resulted from rainfall on lands that have been plowed and uncovered in their cultivation under a system of farming brought from Europe where there are no torrential summer rains. Besides, our ancestors were given four open-row crops when they came to America, and so we have continued to make the mistake of gathering our crops and leaving the land all the rest of the year unprotected. With no vegetation to break the fall of the rain-

drops and to hold the moisture in the ground around plant roots, the water runs off, and, as it goes, it carries with it a little of the soil in suspension and some of its valuable mineral elements in solution. The extent of this depletion depends upon the lay of the land, upon the character of the soil itself, upon the kind of cultivation, and finally upon the amount of the rainfall. Here in the North, we are fortunate in that snow covers our land throughout most of the winter months. The South is not so fortunate.

Some idea of the extent of this destruction can be gained from the estimates of Russell[4], the physical geographer at Louisiana State University, who concludes that two million tons of silt are discharged each day into the mouth of the Mississippi.

When the Soil Conservation Service was established in 1934, a government survey was made of the condition of our lands. In this country there are a total of 1,900 million acres. The report was that 143 million acres were in mountains, canyons, and bad lands, 57 million acres were completely destroyed for tilled crops, 225 million acres were three-fourths or more destroyed for tilled crops, 775 million acres were one-fourth to three-fourths destroyed for tilled crops, and 700 million acres were less than one-fourth destroyed for tilled crops. But only about 415 million acres of the United States are available for cropland. Of this, 60 per cent, or 250 million acres, are of such poor quality that they return only a small yield or are subject to continued erosion, leaving 40 per cent, or 165 million acres, which can be safely cultivated. With proper and improved practices now being taught to the farmers of the world by our United States Soil Conservation Service, a large percentage of the land now being damaged each year can be returned to the good land, and our total can be raised to 300 million acres suitable for cultivation. It is understood, of course, that these figures do not include the 100 million acres now in woods and pastures or those lands which are improvable by irrigation and drainage.

FERTILIZERS

Today a great controversy is being waged between those who would use commercial chemicals (artificials as their opponents call them) to replace whatever mineral elements are missing from the soil and those who insist that only organics from a compost pile should ever be applied to restore fertility to the soil. Sober minds in both camps realize the importance of humus.

This controversy goes back to the very beginning of the use of commercial fertilizers, for the suspicion that the "complete fertilizer" (composed of nitrogen, phosphorus, and potassium) was not all the food that plants need is almost as old as the fertilizer industry itself. In 1866, two German investigators grew wheat in a well-water solution of artificial fertilizer and also in a solution of natural manure. They concluded from their experiments that plants could not thrive by chemistry alone.

Between 1900 and 1910, the United States Department of Agriculture carried on a series of experiments on organic and inorganic plant foods. These experiments established the limitations of inorganic fertilizers and gave new emphasis to

the factors involved in soil improvement, quite aside from any nutrient material such as soil bacteria, fungi, and animal life as well as the fertilizing factors in auxins, hormones, enzymes, and the other newly discovered activating agents.

Although these researchers were often on the track of the trace mineral elements about which we hear so much today, they missed them because the elements were present in such small amounts that the unsensitized minds of the investigators could not possibly conceive that they have a part in plant life; consequently, the trace elements were called minor elements and looked upon with mild contempt as contaminants. When studies were made of goiter and anemia in man and animals, it was appreciated that some of these minor elements must play a major role in the physiology of mammals. When the land in certain citrus and pecan groves began to "play out," to keep the southern planter from going to the Southwest and Texas orchardists from moving to California and California growers from giving up, they were compelled to learn that these minor elements, although they were present only in traces, play far from a minor part in the economy of our nation. They found that the requirements for nitrogen, phosphorus, potassium, and calcium were not reduced by the use of these other elements. It was rather that these major elements worked all the better when the deficiency of these trace elements was made up. In fact, the normal utilization of potassium, phosphorus, and nitrogen appears to depend in some important way upon the satisfaction of the associated requirements for these trace elements. As Mowry[5] puts it:

> "While the inter-relationship of several of the elements in plant nutrition is far from being completely understood, the increased yields, the vigor of growth, and the disappearance of 'deficiency symptoms' have established the essential character and practical value of many elements in the fertilizer program which only a few years ago were given no consideration."

So we see that a balanced fertilizer program is the surest guarantee of a balanced food.

PLANT GROWTH

In considering the growth of plants, we may think of it first as a photosynthetic performance. This action builds the woody framework of the plant, using only a very limited amount of the soil's fertility mainly as a catalytic agent to set up the factory and supply the fuel. In the second place, as Albrecht[6] has pointed out so many times, plant growth is a biosynthetic performance into which the soil's fertility enters directly to have its phosphorus, sulphur, nitrogen, and so forth made up into protein, vitamins, hormones, and other compounds truly valuable for body function, rather than for fuel only. It is soil, then, rather than the sunshine and fresh air, that determines how well the plant really gives us nourishment. For us the highly proteinaceous plant is the plant of choice, but for the insect pest it is the more woody, less proteinaceous plant that meets the demands of his nutrition. So insect pests do not bother the good farmer as long as there are the fields of the poor farmer to ravage. I always wondered why the bugs do not know good food when they see it, especially since all native animals have excellent dietary instincts. It was not until the entomologists at the University

of Missouri showed that these insects do know what is good for them that I understood that what was good for them is not good for me. This is another of nature's nice adjustments!

In this connection Albrecht points out that our crop juggling to overcome the loss of fertility puts too much emphasis upon volume rather than upon value. These crops may retain much of their service in giving us a supply of energy, "go" foods, as Fink[7] has named them, but may lose much of their service as "grow" foods as well as carriers of soil elements elaborated into complex organic compounds of high nutritive value. We can see what erosion has done in our land, but we fail to appreciate what soil depletion has done. We do not seem to realize that our stewardship calls for the return of what we have borrowed.

Unconsciously we have gone from a *proteinaceousness* and a high mineral content in our plants, which were growing on a soil under *construction,* to a *carbonaceousness* and a mineral deficiency in plants growing in soils under *destruction.* The nutrition of our people and our animals at the same time tends to go from a level of bone building, sound construction of teeth of superior quality, and muscle making a fecund reproduction to hydration, obesity, excesses of weight and weakened bones, and flabby muscles, to say nothing of decayed teeth, toothless mouths, alveolar bone disintegration, and other troubles.

The declining fertility of our soil compels us to put the emphasis on tonnage and bushels and to give to our domestic animals fattening feed instead of food that would have made them strong, muscular, and healthy and presumably of higher nutritive value when their flesh is eaten by man. This is not all presumption either, for we do know that the vitamin B content of the muscles of a pig can be influenced by the food he gets. We know too that the typical pig ready for market is a sick animal—the victim of obesity, and would die long before his time if we did not rush him to market for the city dwellers to eat.

THE ROLE OF MINERALS

The minerals used in building plants comprise only about 5 per cent of the soil. Another 5 per cent consists of the organic matter or humus, and the remainder is composed of inert material that serves as a support for the growing plant. What is not so often realized is that the clay in this inert mass forms a colloidal solution for the adsorption of foodstuffs and their exchange for hydrogen with the growing plant. So when such a plant food as lime, for instance, is all used up, this colloidal clay is loaded with hydrogen, and we say that the soil has become acid. This is true enough, but what really counts is that the soil has run out of calcium and other nutrients.

The mineral elements that should be in a soil may be missing from the land for several reasons. They may be lacking because they were not in the original rock from which the soil was weathered out. Again, through the centuries, they may have been washing out. Or they may be so closely locked in the underlying rock that none can be freed. On the other hand, faulty agriculture practices may have depleted the soil of certain essential minerals. Because our forefathers brought from Europe the continental system of land cultivation, totally unsuited to our

driving summer rains, we have soil erosion and loss of essential minerals. Finally, economic pressure brought on by the mechanization and the consequent industrialization of our people has compelled our farmers to mine their land, not manage it. Thus, for several generations the farm income has come from the sale of its soil fertility and not from real wealth manufactured on its fields.

I do not need to tell dentists that good nutrition is the key to good dental health and that the only way of eliminating dental disease and its effects is to begin with the care of the teeth of young children, but I can use this occasion as a sounding board to tell the American people through the newspapers and radio that they will never get good teeth from a dentist any more than they can get good health from physicians. We are, dentists and physicians alike, all devoting our lives to patching up the bodies of sinners against the laws of hygiene. We are proud of the high character of our work and of the skills that we have to offer to the sick and diseased, but there should be no sick. We sometimes forget to tell the public that all organic diseases are not reversible. We may make repairs, but we can never restore the body to what it was before the disease struck.

I do not need to tell you that compulsory health insurance laws cannot make dental treatments available to all of the citizens. Not only would it require more than ten times the number of dentists now in practice, but it would cost so much that no people could afford it.

I do not need to tell you that recent surveys have shown that there is at least ten times as much dental work waiting to be done as there are dentists available to do it. Only one tooth in ten can, therefore, receive attention. Our welfare-minded citizens, without giving it too much thought, would like to nationalize the dental profession. They would solve this problem by a scheme which might go a long way toward bankrupting the nation. Certainly it would lower the standards of your work. The scheme, of course, is purely a "phony" attempt to get funds for spending and power, and in the long run it will cost more than the nation can afford. To enlarge the dental schools and train ten times as many dentists as we now have would cost a tremendous sum of money. In addition to the cost of building, equipping and maintaining these schools, what is more important is the loss of 24,500,000 working years from productive employment. We would be taking out of productive employment some 700,000 of our brightest young men. Those politicians who are bent on socializing America forget that dentists, like physicians and nurses, never produce one penny's worth of real wealth. Theirs is a service profession. They are, in fact, a luxury which only a prosperous society can afford. Prevention must, therefore, be the answer to the problem of adequate dental care.

We could do away with the need for dentistry in the next generation if we would give our nation the optimal diet that we know how to select. If we will give our pregnant mothers the very best diet that we know how, it will insure them that their babies' teeth will be set squarely and will be equally spaced in the jaw and that the jaw will develop properly as the teeth grow. There would be no crooked teeth and no deformed narrow faces which are so commonly seen on our streets today. All of our people will have regular facial features and good posture,

and our women will be beautiful. Thus, we shall do away with the need for the orthodontist. What is more important, however, there will be built into the teeth of that baby a quality of tooth construction that will be superior. If the child is nursed by his mother, he will come off of her knee with teeth that will not decay, provided he gets a proper diet in his day, and so we shall do away with the need for most of the services of the personal dentists.

Here we come up against a great obstacle to the solution of our problem, and that is the miseducation of our people by the hucksters who sell white flour, candy, and pastries, especially the sweetened varieties which, in addition to the sugar they contain, have a goodly quantity of phosphoric acid to help destroy our school children's teeth.

If, however, we could get the American people to have a new set of values and go on a diet of whole-grain flour, no sugar, vitamin-rich mineral, rich fruits, and leafy vegetables grown on soils of full fertility, teeth cared for under such conditions would last as long as their owner, even if he lived his rightful 120 years, and so would go begging the work of the exodontists. So, too, at the same time would disappear all those systemic diseases that go with infected teeth and which plague physicians so much.

The nation can and may well bankrupt itself trying to take better care of more decayed teeth and infected gums as the teeth decay with more rapidity year by year. On the other hand, we could do away with 90 per cent or more of the needs for dental care in the next generation if our people would eat the more wholesome, better tasting diet which we know how to prescribe. The great obstacle, however, to doing away with dentists is the poor sense of values which our miseducation has given the American people. A country that spends more on cosmetics than upon health, more on chewing gum than upon dentistry, ten times as much on liquor and tobacco as it does upon churches and welfare work needs re-education and a new sense of values.

So far in this paper you have been urged to fight and fight hard against the socialization of your profession. I would add all the emphasis of which I am capable that you do this very thing, but I warn you that this is not one of those issues which can ever be settled. Those who believe in the teachings of Karl Marx, be they socialists or communists, or just fellow liberals, will not down. In truth, these "liberals" are not true liberals who believe in the dignity of man, but are "liberals" only in the sense that they are generous with the taxpayer's money. All of these are determined to redistribute American wealth and make paupers of all of us, and they will not stop—they will not be defeated. They can only be conquered by the promotion of a true prosperity built upon production and upon surplus which we may use to promote health and happiness.

Every dentist and every physician who has a social conscience should make it his major job for the rest of his life to re-educate every person with whom he comes in contact to the dangers of social collectivism. We, as biologically trained citizens, must make our patients and our neighbors understand that group life based upon mutual cooperation with full individual responsibility is the road

to sound and enduring social progress. If we do not do this, then the personal liberty and the dignity of the individual that are the bases of the Judaic-Christian concept and for which your ancestors and mine fought and won the American revolution and established here a democratic republic will be lost in the whirlpool of collectivistic democracy. Karl Marx is the anti-Christ, and those of us who are not socialists or communists must stand up and be counted. We must make the people see that personal health will always be a personal problem, that personal preventive efforts alone will give a real solution to the problem of dental care.

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SOME PHASES OF OUR MANY-SIDED DENTURE PROBLEM

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A BEAUTIFUL diamond has many facets. Each facet is a separate task in its making. Each is perfect in itself and all unite in perfection.

So should it be with the dentures we build. Each phase from the first to the last presents its own problems. Each step must be our best, or something will be lacking at the end. These steps group themselves into three main categories: (1) steps intended to minimize unavoidable resorption, (2) steps promoting psychologic adaptation to the change from natural to artificial teeth, and (3) steps used in solving the mechanical problems of denture construction.

The solutions for these problems overlap. For instance, an optimum nutrition lessens resorption while improving personality problems simply because a well-nourished person feels well; a fine prosthesis helps to reduce resorption while improving the mental attitude, too. Even so, our efforts broadly group themselves along the lines of these steps.

Let us start by deciding what we are trying to do for our toothless patients. We hope to give an artificial restoration of the natural chewing mechanism to people who are reaping the toll of degenerative disease which affects not the mouth alone, but the whole body. In this impaired condition, the glandular functions, which include digestion, have lost some of their potency. They have lost so much that we are usually confronted with a weakened digestive tract demanding that oral preparation of food be as efficient as the skill of modern dentistry can make it. In order for digestion to proceed efficiently, nutriment should be finely divided to expose the largest possible area to the series of simplifying chemical processes which make it usable for growth and repair. Therefore, the edentulous state must be accepted as primary evidence of the need for an efficient masticating ability.

To attain this end requires skill, patience, and a knowledge of the obstacles which can distort our efforts into a painful misfit, instead of the comfortably efficient prosthesis we set out to build. An analysis of these obstacles shows them to lie in the mechanics of instruments, in the mechanics of the human body, in the physics of the materials we use, and also in the mind and physiology of every individual patient.

OBSTACLES

Among restorative procedures, there is first of all the difficulty encountered in registering the form and dynamic relationships of the human jaws in all their

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variations and functions. Second is the mechanical adaptability of articulators, most of which compromise to some extent in positions or paths intermediate to the ones used for adjusting the instrument. Next comes the matter of expansion and contraction of the things we use in the laboratory procedures. Until we are given cast and flasking materials which do not change in volume and until we are able to control absolutely the volumetric changes inherent in our impression materials and denture bases, we can never produce a really perfect set of dentures. In addition to all this, we may have to work with patients presenting thin ridges, variable tissue resiliency, and, frequently, impaired attachments between the mandible and the skull in the mechanisms of the temporomandibular joint.

For brevity in this discussion let us assume that accurate impressions and dynamic registrations can be accomplished and that an articulator can be manipulated to reproduce them. That leaves us with the problem of material changes and the problem of tissue resiliency in the ridges and in the ligaments and muscles of the temporomandibular joints.

How do ligaments perform? They are like guy wires. Their function is to maintain normal approximation of the condyles in their fossae. They lack ability to shorten themselves to less than their original length when erosion of the articular surfaces creates an articular looseness, permitting the entire mandible to tilt when unbalanced occlusal force is applied upon it. This tilting, especially when coupled with displaceable ridges, too often keeps us from finding interfering points in the occlusion.

Processing errors are decreased by careful handling of materials and equipment. Yet many steps in any precision technique are necessarily designed to overcome discrepancies. An attempt is made to compensate for processing errors by split-cast milling methods in which the processed dentures, still on their casts, are remounted on the articulator and the occlusal surfaces ground to harmonize with each other. This is a valuable aid in eliminating trouble, but it cannot do so completely because it restores only the original relationship between the occlusal curves and the bows of the articulator. The errors caused by the expansion of the casts and the shrinkage of the denture base still remain to cause a malrelation between the cast side of each denture and the articulator bows. Then when the dentures are seated in the mouth, this malrelation between tissue surfaces and casts is converted back into a malrelation in the occlusion. Upon inspection under ordinary conditions, some degree of this malocclusion will pass undetected because the previously mentioned resiliency in ridge tissues and joints conceals it from observation.

By another method attempts are made to control laboratory errors by finishing one denture before the other, then building its mate to articulate with that one. This again is incomplete, retaining some degree of change in the finished product.

Each patient's attitude toward his dental problem, his ability to adjust himself to unpleasant situations, and, most important of all, his ability to maintain a healthy, relatively unchanging foundation on which to seat his dentures in unconscious comfort can determine whether the finest prosthesis will succeed

or fail. These are the psychosomatic factors which alone of all obstacles in our denture problem may prove insurmountable. Emotional age, emotional environment, habits of thought, food habits, digestion, assimilation, and metabolism are all tied together, should be studied together, and treated together, or success may be incomplete.

DIAGNOSIS

Now that we have considered some of the negative factors in denture construction, let us proceed to the positive, or actual, steps involved. To place our efforts on a sound foundation, we must make an adequate diagnosis in order to predict the probable degree of success inherent in the case at hand. To do this we must look beyond the mouth and consider the patient as an individual in all his relations to the dental problem. Why did he lose his teeth? If periodontoclasia was the trouble, we must make certain that the factors which caused loss of alveolar bone around the natural teeth are not still operating to cause excessive loss of bone under the dentures. If active degenerative disease is evident, we must try to find the cause and treat the case ourselves or endeavor to secure help from allied professions. At best, we will avert incapacitating ailments or guide someone back to a forgotten comfort and vigor; last, but not least, we will protect ourselves by sharing with the patient the responsibility for troubles which are beyond our control, before they occur.

Many factors may be encountered in running down oral degenerative changes, but they usually evolve into three main categories, namely, hereditary, emotional, and nutritional. Pottenger,[1] Price,[2] and others have conclusively shown that prenatal development and even the health of both parents prior to conception profoundly influence the course of our physical selves all through life. If we learn, for instance, that the patient's mother suffered from morning sickness while carrying the child, or if she possessed irregular teeth or suffered from much dental disease, we are justified in assuming she was herself physically deficient, because all of these conditions are usually symptoms of subnormal metabolic or nutritional states. We are safe in assuming that the patient has received the deficiency to an increased degree and will be less likely to respond favorably to therapy than one who comes from a healthy family and started life with an ideal development of his own. Knowledge of hereditary weakness should never keep us from trying to improve a patient's physical status, but only forewarn us of expected complications, because any improvement in health increases denture comfort and lessens denture troubles.

More physicians are beginning to understand the dental problem, thereby making available competent help in treating organic and functional derangements. However, a well-trained dentist need not hesitate to handle the case himself, within the limits of his training, if cooperation is not available. Likewise, we should recognize that the emotional background strongly influences and is influenced by both physical health and reactions to unpleasantness. Without a

doubt, dentures do create unpleasant situations, so a knowledge of psychology will prove most useful here.

Worry, grief, or fear may incite nervous habits such as bruxism which can result in much resorption or soreness, or they may only cause a general tenseness which renders the registration of centric or other jaw positions difficult. Relaxation for positional registrations is easily induced by medium doses of some barbiturate, but in other situations a more fundamental approach is required. Occasionally, we may find it necessary to refuse to treat a patient because of emotional infantilism, or we may refer him to a practicing psychologist for counseling prior to treatment. We must always remember that one who is unstable in his emotions may become a vociferous detractor of whoever is trying to help him, rather than face unpleasant facts. Also, a patient laboring under a heavy emotional strain probably suffers from impaired digestion, which, when long continued, may be reflected in the edentulous mouth as an easily inflamed mucosa with rapid alveolar resorption.

A. *B.*

Fig. 1.—Metabolic control of an unfavorable ridge condition. *A*, Before; *B*, after. Dietary therapy decreased engorgement and swelling in the ridge tissues. A 13-year-old celluloid denture was worn, unaltered, while improvement occurred. A new denture built to conform to the swollen state would have been a gross misfit when swelling left. In this case the author protected himself and the patient by refusing to make new dentures until dietary treatment showed anticipated results. Hawkins[8] handled the nutritional work on this case. He used methods outlined in his book, *Applied Nutrition*.

We all know how fear, grief, anger, or worry can dry up our secretions, inhibit digestion, and render us temporarily unfit to cope with the problems of our environment. In these troubled times this hazard is very real. It merits adequate attention when it is encountered.

Fortunately, we are better prepared to deal with nutritional troubles than we are those of hereditary or emotional origin, which, though important in their influence on metabolism, seldom nullify attempts to improve the nutritive status. Consequently, let us do all we can to provide the widest scope of treatment, either through our own efforts or by seeking cooperation from others.

In this work a complete set of roentgenograms is prerequisite to the diagnosis. Besides the usual pathologic manifestations revealed pertaining to teeth or their roots, foreign bodies, infection, spiculae, resorptive areas, soft tissue, and

so forth, we can estimate the probability of bothersome ridge shrinkage by studying the trabecular system and cortical bone character. The trabeculae should present a well-defined pattern which braces the cortical plates and peridental lamellas in much the same manner as cross members in a roof truss. The cortical layers should show a good thickness and contrast in density against the underlying cancellous bone. Enlarged blood spaces are usually indicative of active calcium withdrawal, while osteoporosis is evidenced by a breaking down of the cancellar pattern. Either of these conditions should be a red signal, warning us to investigate and institute constitutional therapy, because a weakly constructed or degenerating bone is very apt to fail as a support for any appliance.

A. *B.*

Fig. 2.—Casts made from alginate impressions taken three months apart. *A*, After; *B*, before. The fibromatous mass in the labial fold was reduced by nutritional therapy. This mass appeared from chronic irritation of an ill-fitting denture border. The denture flange was reshaped and prescriptions given. No other treatment was used, and the denture was continued in use. The patient took each day three 6 min. capsules of cold pressed wheat germ oil and 1 or 2 teaspoonfuls of a compound containing one part of defatted cereal germ with one part of powdered, whole, raw (uncooked) veal bone. The patient "couldn't be bothered" with the rest of the nutritional outline and did not otherwise follow it.

These supplements have been effective against several similar lesions, including fibrous hyperplasia of interdental papillae seen in periodontoclasia. They have relieved cornifications of the mucous membranes seen in smokers' mouths. Leucoplakia, confirmed by biopsy, has disappeared or substantially lessened following one to three months use. The tightening of chronically loose teeth during their use is routinely expected. The effect seems to be a function of uncooked bone as a food since the other substances alone fail to produce these results. (Oil, germ, and bone supplements furnished by Vitamin Products Company, Milwaukee, Wis.)

NUTRITION

An adequate nutritional program meant to preserve or improve the integrity of the dental structures may work slowly for some people, but it is always noted for its simplicity. Patient instruction need consume but little chair time, since much information can be imparted in conversation while other work is in progress. First, the patient is asked to keep a food intake list for seven consecutive days. This serves several purposes; among others, it forcefully draws the patient's attention to the dietary problem, and it enables the doctor to build his corrective advice around the patient's established routines. Carefully analyzed, it suggests the basal metabolic state, digestive power and utilization ability, probable reasons for degenerative changes, and what to do about them.

To control resorption the diet itself should be high in dairy products, meats, fruits, and vegetables, with variety in each. It should be fairly low in grain derivatives and practically devoid of both white flour and refined sugar. Emphasis should be placed on the use of foods in their entirety. This means the ingestion of whole grain foods in relatively small amounts, peelings and rinds whenever edible and free from poisonous insecticides, and, also of great importance, the glands of animals in addition to the ordinary muscle cuts. This means heart, liver, kidney, sweetbreads, brains, and so forth. Sea food used liberally to supply iodine and trace minerals completes the basic outline, although moderation in fats is always advised to promote calcium utilization. It is highly important that the fat which is used should be of the chemically active type, rich in unsaturated fatty acids, lecithin, and related compounds. Artificially hydrogenated fats have lost many important abilities to react in glandular and metabolic processes. Most natural fats and oils contain radicals and double bonds which favorably enhance the transport and activity of vitamins and cholesterol and provide raw material for forming steroids and gland secretions, in addition to yielding calories. Lightly cooked animal fats, real butter, unpasteurized cheeses, eggs, and fluid cooking oils are all desirable sources. Heart, liver, kidney, brain, and sweetbreads are important as sources of preferred types of fat, just as they are of the better known special proteins.

The author is fully aware of current medical trends toward drastic restriction of fats, intended to curb high cholesterol blood levels. But experience indicates that the liberal provision of accessory food factors which facilitate the use and elimination of fats in normal metabolism is a better way of meeting the problem, especially because drastic fat intake restriction imposes drastic reductions in the highly necessary fat soluble vitamins. A parallel might be drawn with the man who refused to put oil in his car because it fouled his spark plugs, when what he needed was some automotive vitamins, in the form of a set of piston rings, to keep the oil in its place.

When the quantities of food taken are small, vitamin and mineral supplements are indicated. Sometimes thyroid extract,* hog stomach, pancreas, hydrochloric acid in buttermilk, papain, diastase, soy lecithin, glutamic acid hydrochloride, or some other digestive or glandular aid is also needed to encourage the body to convert good food into living tissue. Diets which are changed gradually are better tolerated, and cooperation is more permanent than when drastic measures are inflicted at once. General dietary information is given as the occasion offers. Succinct or surprising statements interjected into lighter talk seem to be heeded most. Examples of some homespun ideas the author has used are:

"Eighty per cent of the need for fillings disappears when white flour and sugar are not used. We are then forced to consume other foods of higher value. Refined sugar in even small amounts deranges the blood chemistry of calcium and phosphorus for many people."

"Our mechanical advancement in the treatment of foods has outstripped our evolutionary advancement in adapting to them."

*Thyroidea seca (U.S.P.) or whole dessicated thyroid.

"Today's overburdened dentists would feel rather silly in a perfectly fed world with little to do."

"Citrus peelings contain ten times the vitamin value of the juice. Evaporation of water occurs at the surface of any object, therefore nutrients which are carried through plants by water are left behind in the outer leaves, skins of fruits and vegetables, and hulls of grain."

"Green outer leaves of lettuce, spinach, beets, cauliflower, celery, and so forth, as a rule, have forty or fifty times as much good in them as blanched inside leaves. Excessive washing, paring, or cooking removes or destroys much that we need. Milling and processing do the same thing."

"Most fats, starches, and sugars only provide fuel for heat and energy, but proteins and minerals provide the building blocks for growth and repair. Glandular secretions are put together from proteins; animal proteins are more like our own than vegetable proteins, so we need meats and dairy products more than we do starches, even when work is light."

"Water bathes the earth, finds its way to the sea. Therefore, the sea contains all elements, and food from the sea will contain them, too. Land foods may not always be adequate in these vital minerals"—and so on, giving a little at a time, so each point will be remembered.

These statements are all essentially true, but they are not set forth here as unalterable scientific facts. They are merely some of the things the author tells his patients to help them solve their dental problems.

REQUIREMENTS OF RESTORATIONS

Superficially, mouths differ widely in their requirements for full dentures. Actually each involves the problems of tissue adaptation at rest and in function: sufficient border extension to prevent the entrance of air between mucosa and denture, establishment of vertical dimension, esthetics, phonetics, and last, but of primary importance, wide distribution of stress against the ridges in every functional relationship of occlusal surfaces. This last point includes the registration of jaw movements and the building of a harmonious occlusion.

A single paper cannot be a complete course in denture construction, so let us stop with a point on each phase just mentioned. Transparent bases show the slowness with which blood returns after tissue has been displaced under a too tightly fitting denture. They show why unequal displacement between hard and soft areas in function is less harmful than leaving some of the denture-bearing areas in a prolonged condition of lessened circulation after biting pressure has been removed. We must fit not only the chewing mouth, but also the resting mouth, and evolve a technique which is kind to the tissues in either state.

Impressions.—Peripheral extensions must reach a reflection of tissue or an area soft enough to follow unavoidable denture movements in order to maintain border adaptation, but they must not impinge on active muscles hard enough to cause loosening or soreness. Within these limits we should avail ourselves of all potential stress-bearing areas, in order to provide the widest possible distribution of occlusal stress upon the mucosa. Distribution of force means less pressure per square inch and less resorption per year.

Vertical Dimension.—In speech, teeth do not noticeably occlude unless the vertical dimension has been opened too far. To conform with this, the vertical opening between jaws can be set at any point consistent with comfort and esthetics up to within a millimeter or two of occlusal contact when rapidly pronouncing words containing "s" or "x." A good test sentence is "sixty-six sailboats sailed the Mississippi in 1666," because it contains the necessary sounds and is long enough to produce relaxation when saying it. Beyond this point lies trouble, perhaps clicking in speech or clenched jaws lacking a rest position. Another test in use is "sixty-six, A, N, C." Ending the test on the letter C visualizes a close approximation of the rest position and free-way space.

A. *B.*

Fig. 3.—*A*, Centric; *B*, protrusive. Note how the length of protrusive movement in an ideal dentition equals approximately the length of one cuspal incline and how the inclination of cuspal slopes approximates the compromise path formed by the resultant of the condylar path working in conjunction with the incisoprotrusive path. Also note the contact of all teeth, including the third molars. (Skull in collection of Dr. M. M. House.)

Esthetics.—Esthetics are like music. Someone has said, "If you like it, it's music; if you don't, it's noise." So we must give our dentures eye appeal because people other than the patient judge our work by how it looks, not by how it feels. Even many of our patients put the same standard first. Fortunately, careful utilization of technical knowledge allows a fair degree of latitude in placing teeth to appear well and still function satisfactorily.

Phonetics.—Phonetics seem to take care of themselves when teeth are placed in the correct relations to the ridges, that is, in simulation of natural dimensions before any resorption took place, when the incisal plane is esthetically correct, and when excessive thickness of lingual or palatal surfaces is avoided. Crowding of the tongue by the maxillary bicuspids and an unnatural shaping of the inciso-

Fig. 4.—Protrusive balance simulating an ideal natural dentition. Conventional cusp forms can be manipulated to produce an ideal protrusive balance only when the centric-to-incisive path is short.

A. *B.*

Fig. 5.—Centric occlusion. *A*, Cradled cusps as seen in new dentures before resorptive closure has occurred. *B*, Migrated mandible destroys the cradled relationship of the cusps. Note the protrusive occlusion of the teeth as a result of resorptive closure, even though the mandible is in centric position.

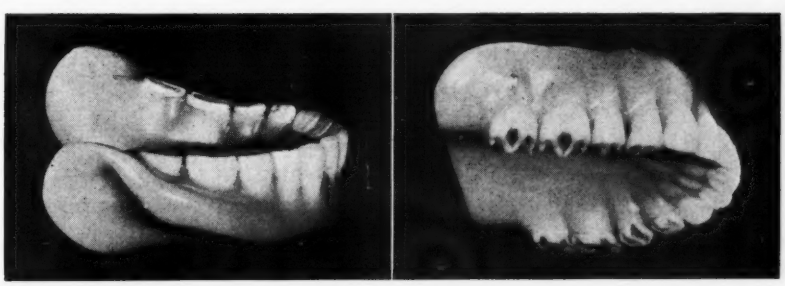


Fig. 6.—Cross blade occlusal design. This pattern, developed by the author in 1937, was ground from the original style of French's posterior teeth. Note the transverse cutting blades in the upper teeth opposed by lingual and buccal blades of the lower teeth. Actually, the lower posterior teeth are narrow so that each lower tooth resembles a flattened buccal cusp, hollow ground lengthwise.

palatal region are the most frequent sources of phonetic trouble. In this connection, it should be noted that many enlarged tongues are edematous from a general retention of water in body tissues. Restoration of metabolic balance in conjunction with an adequately balanced diet can sometimes shrink the tissues and apparently increase tongue space without any change whatever being made in the dentures.

Occlusion.—Now we approach the apex of the whole prosthetic problem. The part which may be perfect in itself, but which can fail in its purpose because of imperfect preceding steps. Here lies the explanation for emphasis on diagnosis in all its phases and emphasis on adequate treatment calculated to support properly the restored dental organ. We ask ourselves, "What kind of occlusal surfaces shall we build to distribute biting force as widely as possible? How shall we cut food to an ideal fineness?"

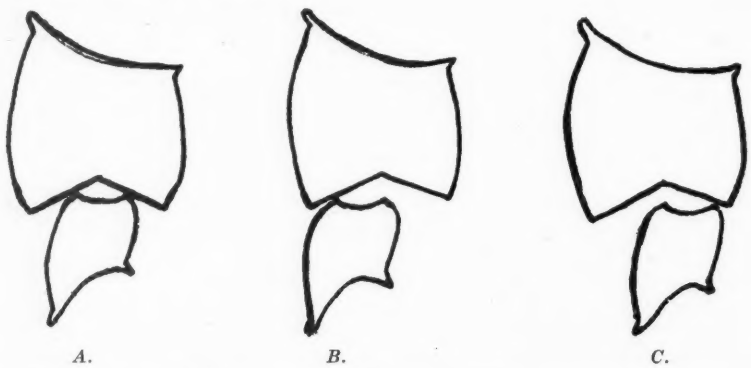
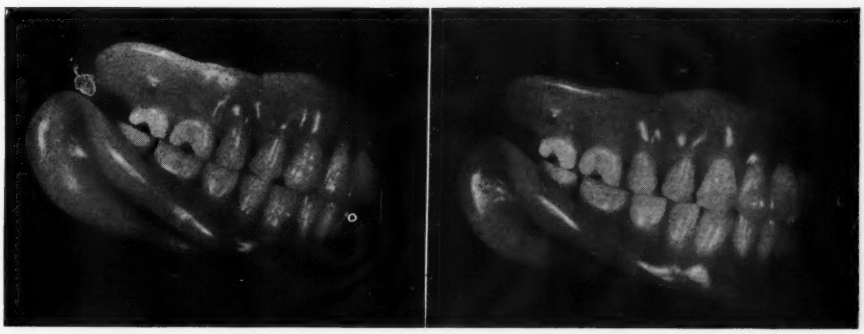


Fig. 7.—Buccolingual views of cross blade occlusal design. *A*. Centric position; *B*, buccal, or working, contact; *C*, lingual, or balancing, contact. Note how the food must be trapped in the sulcus of the lower tooth to be crushed and cut as the movement toward centric progresses. Milling and wear in this type of occlusion can only increase the intimacy of contact and result in greater comfort and efficiency. Efficiency is not lost. The buccolingual angle of each upper tooth will vary with the degree of slope in each condylar path, in the incisal path, and with the distance from rotation centers. It is a resultant of these factors.

Nature provides three actions to shred food: (1) the shearing or scissors action between incisors from which they derive their name, (2) the punching action of sharp cusps to tear holes in fibrous material, (3) the slicing action of cusps gliding through sulci in harmony with the lateral rotation centers of the mandible.

Ideal dental development in primitive races shows little vertical or horizontal overlap, and consequently vertical forces predominate on the roots of teeth placed in ideal jaws. It is true that there is some curvature of the occlusal planes, but it is needed to compensate for the slant of the condyle paths in function. This means that a vertical force applied to a natural tooth is absorbed by the entire peridental membrane, not by just one-half of it, as happens when pressure from a direct lateral thrust is resisted. Following this principle, we should try to direct pressure on ridges as nearly vertically as possible in order to utilize all of the available stress-bearing areas at one time. Cradling of cusps in fossae by

natural teeth creates vertical pressure by balancing one incline against another. This cradling would be highly desirable in our dentures were it not for one inescapable fact. It is this: When closing, the body of the mandible moves in an arc, resulting in a degree of forward movement approximately equal in length to its vertical motion. For this reason, artificial dentures do not retain one centric



A. *B.*

Fig. 8.—Lateral views of an early adaptation of the cross blade design all in porcelain. *A*, Centric; *B*, protrusive. This case presented low condylar angles. It was made in 1938 by the author.

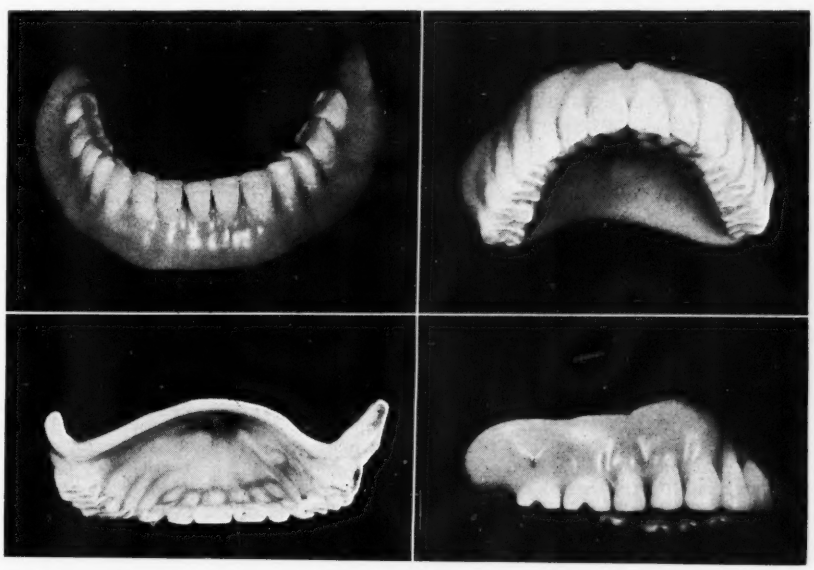


Fig. 9.—Details of all porcelain cross blade patterns of occlusion. Note the sharp cutting ridges and large escapeways. This set of dentures is identical in pattern with the case Hardy faultily described from memory.[4] In the Houston study this pattern achieved 95 per cent masticating efficiency.

position indefinitely, but are subject to early and continuous change leading to resorptive closure. So slight a thing as displacement of the denture-bearing tissue changes the centric relation some, in a forward and upward direction, so that dentures are driven to a different position, which is compensated for at the expense of the mucosa. On account of this limiting factor, properly coordinated cuspless

teeth, with their lower inclines, are more likely to maintain their efficiency without damaging the ridges than regular anatomic designs. They can usually be balanced to direct pressure nearly vertically in any degree of protrusion, whether that protrusion be induced by mandibular function or by resorption.

From these observations we can devise an occlusal form which will utilize nature's shredding devices in a different way, will be easy to build, will be efficient in service, will maintain its efficiency when some inevitable resorptive closure occurs, and will direct masticatory force as nearly vertically on the ridge as may be possible.

Nature forces points through food to shred it; we can accomplish the same thing by forcing it against ridges and into depressions between ridges to break it up. Nature shears, and we can shear, too, not only with incisors but also by using posterior blades which cross one another and which are purposely uncoordinated with the lateral rotation centers to produce a scissorslike action between their occlusal surfaces. Nature slices, and we can also slice as cusps and ridges glide through sulci or against opposing planes. By using nature's actions assembled to fit our problem, we can easily achieve an efficiency very nearly as good or sometimes better than that given us by nature in spite of our limitations.*

Inspection of a genetically undegenerated primitive skull shows how posterior tooth inclines are influenced by the condylar inclination and incisal overlap; how the rise is greatest at the second and third molars because the greatest inclination factor is in the nearby temporomandibular joint; how an ideal natural dentition has very little vertical overlap or horizontal overlap; and how the length of the posterior cusp slopes closely approximates the distance necessary to bring the incisors into an end-to-end relation. A perfectly formed set of teeth contains the

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*This was demonstrated in a study conducted by the National Society of Denture Prosthetists (now the Academy of Denture Prosthetics) in 1941 at their meeting in Houston, Texas. Some twelve or fifteen sets of dentures had been constructed for one patient on the same articulator with the same guidances, on identical casts, and subjected to identical processing methods so that all were alike except in the posterior occlusal design. The occlusal surface forms tested included all of the recognized commercial posterior tooth forms available at that time, in addition to several special types not on the market. About one-half of the dentures were made in 1940 by one man (Dr. David W. McLean). The others were made in 1941 by men who were asked by the society to participate. A dental student having unusually good lateral balance and shearing action in the posterior teeth was used as a control. Most of the cases showed an efficiency markedly lower than the control when tested by the patient on identical portions of cubed raw carrot. (The author was told that the efficiency was about 40 to 60 per cent.) The food was unevenly divided and many large pieces mixed with finer material appeared on the testing screens in all cases except two and in the control.

The other two cases and the natural dentition control were very close together in efficiency, but were judged to be in the following order of merit by the assembled society: (1) control; (2) nonanatomic cross blade design; (3) 45-degree natural form posteriors, known commercially as 133L.

It is worthy of note that the cross blade dentures surpassed the 45-degree dentures in efficiency, although the 45-degree dentures had been used by the patient for one year so that he was thoroughly accustomed to them and had, no doubt, worn the porcelain occlusal surfaces into an ideal contact. Also, the cross blade set alone of all those tested had been milled in the patient's mouth with the help of a resilient central-bearing point and was recut as described later in this paper.

All the dentures were milled on the articulator by a split-cast method after the acrylic bases were processed. Also, each operator had an opportunity to spot-grind his work in the mouth previous to the mastication test.

basic elements of design necessary to maintain balance in all its working relations. The dentures we build should also harmonize with the frequently malformed skeletons on which they are placed.

Tooth Form.—There are two factors governing the unavoidable minimum length of cusps. The first we cannot control because it lies in the inclination of the paths of the heads of the condyles in function. The other is the varying angle of incisal guidance deemed necessary for pleasing esthetics. Usually, just a moderate incisal incline is needed and often none at all when an adequate horizontal overlap can be used.

The working combination of these two factors, the condylar slope and incisal guidance, determines what angulation is required between buccal and lingual borders of posterior teeth. It determines what the mesiodistal angulation of the occlusal plane shall be and whether we shall set up the plane as a unit or break it into steps to keep within the bounds of the denture space. When deciding whether to cusp or not to cusp, we have no choice; the needs of our patients tell us what to do.

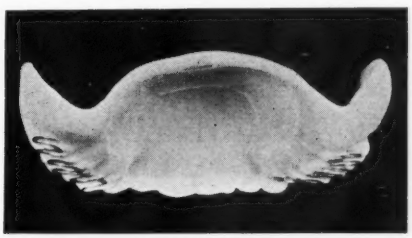


Fig. 10.—Minimum cusp teeth are far from flat when accurately harmonized with factors dictating occlusal paths. Each occlusal surface assumes a pattern of its own when built or worn to harmony.

Steep condylar and incisal inclinations force the use of sharper angles in the central fossae of posterior teeth, which, in turn, create longer points on the occlusal surfaces of the teeth when they are formed to harmonize in functional movements.

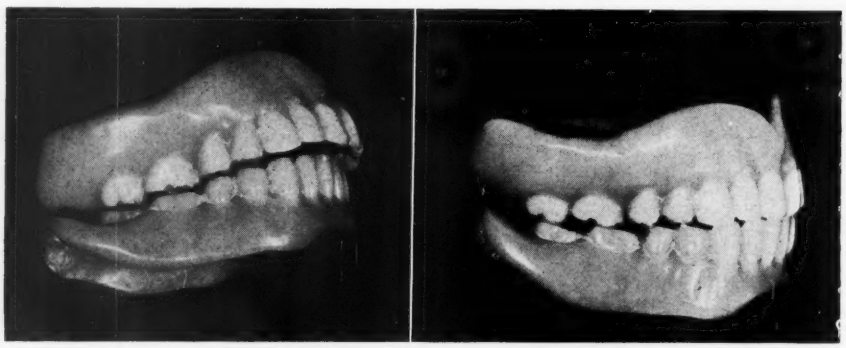
Shallow inclinations in either or both of the incisal guidance and condylar paths accordingly reduce the need for cuspal height, which, if excessive, results in heavy lateral thrusts that can tilt the dentures or overload portions of the ridges by throwing unbalanced pressure into limited areas.

Keeping the occlusion free from unnecessarily acute angles in balancing surfaces helps to direct the applied forces vertically against the ridges. When force is absorbed vertically, it is distributed over both the lingual and buccal aspects of the ridges. When the force is directed laterally, only one-half of the ridge surface is working, and the pressure per unit of area is approximately doubled.

There is another condition which frequently bothers us. It is an apparent retrusion of the mandible when natural teeth no longer guide it into a so-called convenience relationship. In order to prevent interference, we must build an occlusion which works freely in every direction from the point (centric relation)

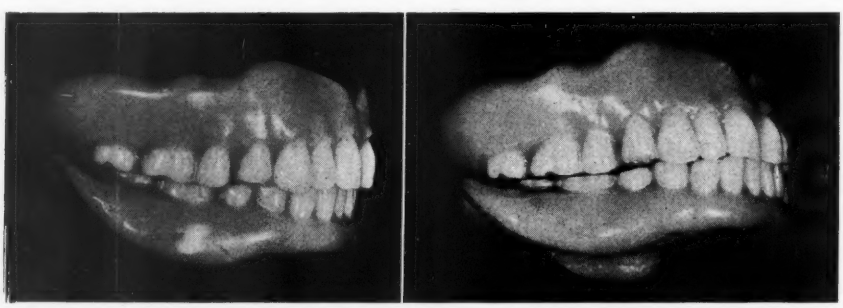
from which all movement begins. Because of this, we sometimes are confronted with a long horizontal overlap of the anterior maxillary ridge. This requires an increased range of movement in the forward direction to reach the incisive position, so that longer mesial slopes are required on all the posterior teeth to maintain uniform balancing contact throughout the required protrusive range. This determines the anteroposterior occlusal form. We have no choice but to comply if we are to provide adequate balance.

Jaw Relations.—Methods used for registering jaw relationships have a definite bearing upon the need for occlusal correction after insertion of the dentures. Correct principles must be followed to achieve success. Those procedures which



A. *B.*

Fig. 11.—Method of setting steep paths to balance in cases where a long protrusive reach occurs. *A*, Centric; *B*, protrusive. The anteroposterior occlusal curve is broken into segments which are placed separately to keep within the available interarch space. Note that contact between the distal edge of the lower teeth and the mesial edge of the upper teeth is freely cleared to avoid driving the lower denture forward against the tender linguo-incisal portion of the lower ridge. This treatment directs force downward and backward against the broadest part of the lower ridge. Reciprocal force against the upper denture does not dislodge it. This handling of potential forces simulates the altered centric occlusion found in cusp teeth as soon as resorption of ridges starts or when a convenience eccentric occlusion is used. Since these conditions are extremely common, they should be planned for when the dentures are made. Such a design also simplifies the problem of building adequate freedom into lateral excursions of the mandibular occlusion. Individual posterior teeth are necessary in cases of this type. The formation of an accurate balance on each tooth is hardly feasible where teeth in blocks are used and the angles are steep.



A. *B.*

Fig. 12.—Method of setting posterior cross blade teeth to protrusive balance when condylar incline has a low angle. *A*, Centric; *B*, protrusive.

make use of some type of Gothic arch tracing without inducing significant lateral thrusts are the most reliable for producing dentures which need a minimum of occlusal correction after insertion.

Occlusal Correction.—In spite of our most careful efforts in construction by even the finest techniques, we nearly always find occlusal discrepancies somewhere when the inserted dentures are checked with articulating paper. Ordinarily, there are differences in the density of carbon marks which are the signs of varying degrees of pressure or interference. We look for carbon spots with white centers which show where the carbon has been squeezed away from small areas of acute porcelain-to-porcelain contact. We may see an apparently perfect occlusion, but we

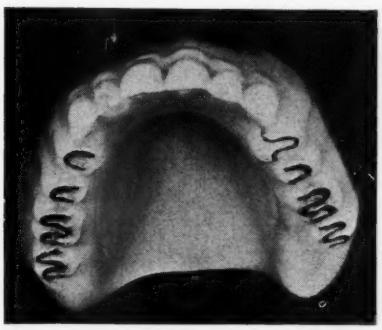


Fig. 13.

Fig. 14.

Fig. 13.*—Metal encased in plastic teeth simplified the making of maxillary occlusal blades. Various metals can be used but they should not be too hard; 18-8 stainless steel and hard gold solders or clasp metals are excellent. Cobalt-nickel-chromium alloys resist wear too long and do not compensate readily for changes in mandibular balance due to resorptive closure. Some aluminum bronzes have a good gold color, but they are also too hard.

Fig. 14.—Metal blades in the upper arch are inconspicuous. When they are momentarily visible in conversation, they resemble fillings.

*This form was suggested by the author in 1941 to Dr. John T. Vincent, of Encino, Calif. In 1942, Vincent made blocks of four plastic upper posterior teeth which had hand-contoured stainless steel inserts in the bicuspids and first molar. Some buccolingual cusp rise was built into the bicuspids and first molars. Protrusive balance was secured by suitably tipping the occlusal surface of the second molar which was made without metal. He set these against French's porcelain lower teeth. Since porcelain is slightly abrasive, they slowly improved the maxillary plastic and metal-contacting surfaces by wear.

A year or so later, the author made individual upper metal and plastic posterior teeth containing 18-8 stainless steel inserts. He followed Vincent's plan of occluding against porcelain below but used the modified pattern shown in Figs. 6 and 7.

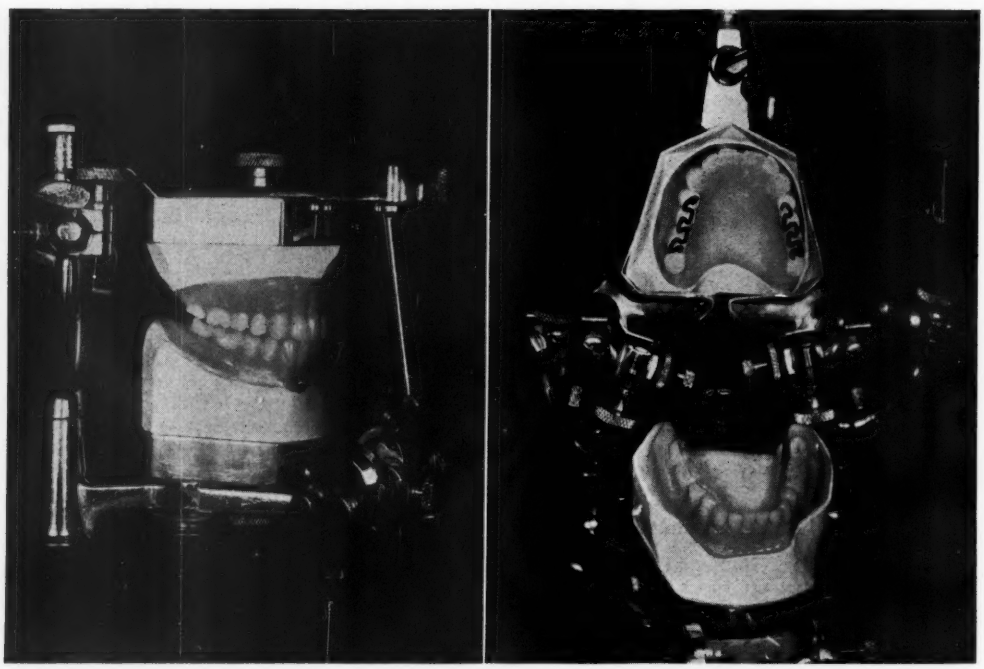
When plastic anterior teeth became available, the author adopted them for use in the upper arch because they wear into freedom when resorptive closure creates anterior interference. He still uses porcelain lower anterior teeth in conjunction with porcelain lower posterior teeth, although his first idea was to use metal blades both above and below. Porcelain provides just enough wear to maintain balance. Metal-to-metal contact is less likely to do this. Further, it does not look well in the lower arch.

About 1945 or 1946, it was learned that Dr. Frank Melton Butler, Seattle, Wash., had made a large number of dentures using metal blades in both arches during the previous several years. A patent (No. 2295864) also appeared, granted Sept. 15, 1942 to the Dental Research Corp., covering teeth containing metal blades encased in plastic.

Hardy[4] constructed a metal insert case of his own design about the time of the American Dental Association Meeting at Boston in 1947.

Experience has shown that the arrangement of blades can be varied widely in form and still function efficiently. Any design in which the upper and lower blades cross each other at an angle will triturate food without any clinically perceptible difference in result or effort. The essential point is that blades shall contact blades during excursions of mastication.

must not forget that very often resiliencies in the ridges and in the temporomandibular joints can hide bothersome occlusal errors that are inherent in our laboratory procedures. Consequently, to be sure that traumatogenic discrepancies are not concealed, we mount a resilient central-bearing device on the dentures and test for high spots again. This device centers the pressure transmitted to the ridges and joints, just as it is centered when a central-bearing technique is used for registering lower jaw movements in the early phases of denture construction. The resiliency of the device also maintains the pressure while occlusal inclines increase and decrease the vertical jaw separation during eccentric movements. Thus, the balancing contact is kept in the center of the foundation when high points touch, instead



A. *B.*

Fig. 15.—Lateral *(A)* and occlusal *(B)* views of a metal insert case made by Vincent about 1945. The author showed this same setup in a clinic at an American Denture Society meeting in Boston in 1947.

of balancing across the arch. Probably, now, only a few points of premature contact will show for correction. By careful selection of the places to grind, the grinding will not lower the vertical dimension at centric position any more than is necessary to establish an even occlusion, and it will provide complete freedom for movement in every direction. The rule for correcting natural form teeth is to grind from the buccal cusps of the upper teeth or from the lingual cusps of the lower teeth for lateral interference, from the mesial or distal slopes as necessary for interference between inclines in centric position, and from the fossae if longer cusps are needed. Trim from the tips of upper lingual cusps or from lower buccal cusps

when shorter cusps are desired. The anterior teeth are formed to yield the best appearance consistent with an ideal balanced occlusion.

Finally, the hand-ground surfaces must be lapped into complete contact in every position because it is practically impossible to bring all points to within less than a few thousandths of an inch of uniform contact by hand. Obviously this is necessary because a surface which does not quite touch cannot cut. So, with the dentures still under spring tension to keep the wear on the high points of the teeth, the patient is directed to slide through various jaw movements while a fine abrasive paste is between the teeth. Four hundred mesh emery or Carborundum is

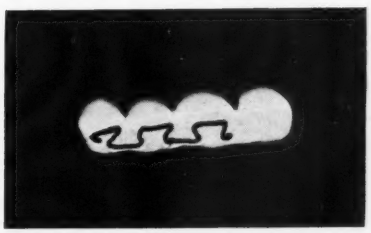


Fig. 16.—Block of four posterior teeth made by Vincent. The bicuspids and first molar contain the metal blade insert. The second molar has no metal in it. This facilitates wear which enhances protrusive balance.

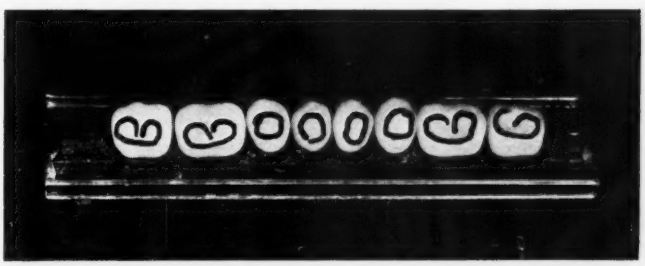


Fig. 17.—Another metal insert pattern formed by Vincent in individual teeth. Strips of gold solder were set into hand-cut recesses, and acrylic resin was cured around them.

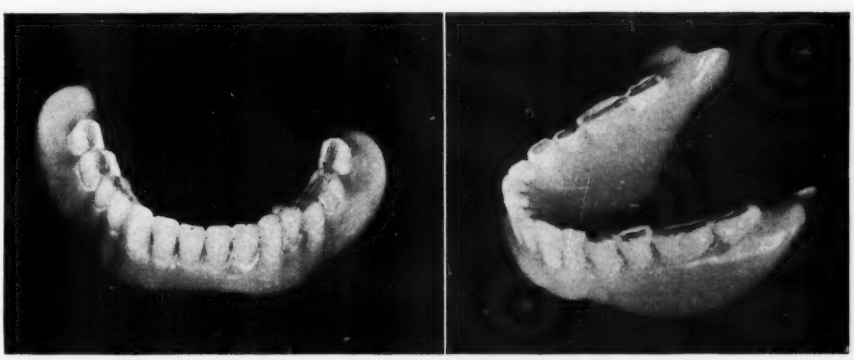


Fig. 18.—Cusp teeth can be modified to integrate with metal blade opponents. Here O mould Austenal lower posteriors have been flattened, then hollow ground, and sharpened mesiodistally to make a narrow occlusal pattern.

about right. Since some vertical closure is inevitable in this method, an allowance of about 1 mm. of excessive opening is made when the teeth are set up in wax, with the greatest allowance being made in the posterior teeth to avoid trimming the anterior teeth too much.

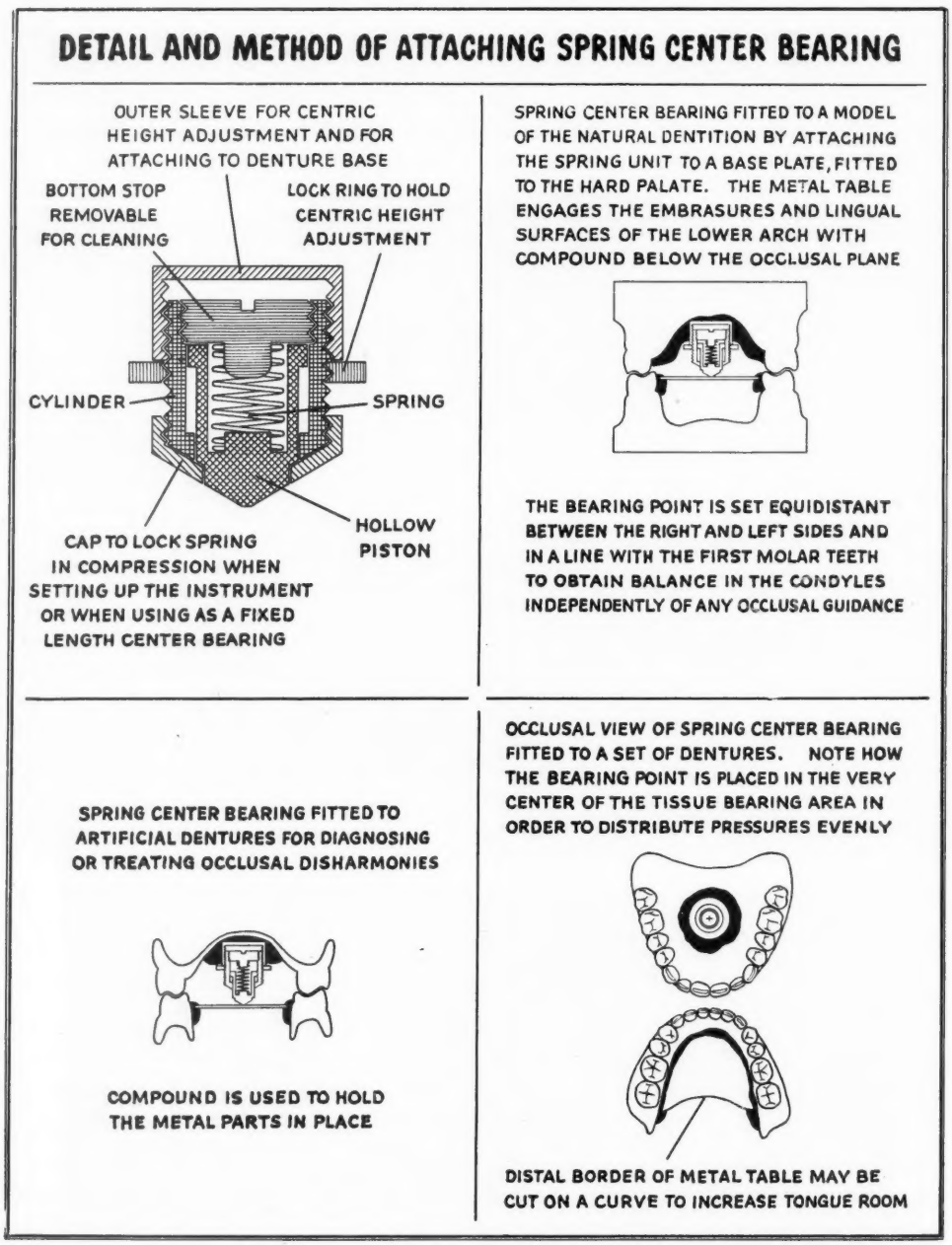

DETAIL AND METHOD OF ATTACHING SPRING CENTER BEARING
OUTER SLEEVE FOR CENTRIC HEIGHT ADJUSTMENT AND FOR ATTACHING TO DENTURE BASE
BOTTOM STOP REMOVABLE FOR CLEANING
LOCK RING TO HOLD CENTRIC HEIGHT ADJUSTMENT
CYLINDER
SPRING
HOLLOW PISTON
CAP TO LOCK SPRING IN COMPRESSION WHEN SETTING UP THE INSTRUMENT OR WHEN USING AS A FIXED LENGTH CENTER BEARING
SPRING CENTER BEARING FITTED TO A MODEL OF THE NATURAL DENTITION BY ATTACHING THE SPRING UNIT TO A BASE PLATE, FITTED TO THE HARD PALATE. THE METAL TABLE ENGAGES THE EMBRASURES AND LINGUAL SURFACES OF THE LOWER ARCH WITH COMPOUND BELOW THE OCCLUSAL PLANE
THE BEARING POINT IS SET EQUIDISTANT BETWEEN THE RIGHT AND LEFT SIDES AND IN A LINE WITH THE FIRST MOLAR TEETH TO OBTAIN BALANCE IN THE CONDYLES INDEPENDENTLY OF ANY OCCLUSAL GUIDANCE
SPRING CENTER BEARING FITTED TO ARTIFICIAL DENTURES FOR DIAGNOSING OR TREATING OCCLUSAL DISHARMONIES
COMPOUND IS USED TO HOLD THE METAL PARTS IN PLACE
OCCLUSAL VIEW OF SPRING CENTER BEARING FITTED TO A SET OF DENTURES. NOTE HOW THE BEARING POINT IS PLACED IN THE VERY CENTER OF THE TISSUE BEARING AREA IN ORDER TO DISTRIBUTE PRESSURES EVENLY
DISTAL BORDER OF METAL TABLE MAY BE CUT ON A CURVE TO INCREASE TONGUE ROOM

Fig. 19.—Author's design for a resilient central-bearing point. It is similar in principle to the design of Dr. Charles Ballard. Each was conceived independently of the other. (Ballard's first.) (Reprinted from the *Journal of the Southern California State Dental Association.*[5])

All these procedures leave harmonizing curves and excessively broad areas of occlusal contact. To restore cutting, shearing, and shredding power, we now rebuild the occlusal anatomy by hand-grinding with diamonds, stones, burs, Joe Dandy discs, or mounted stones. If nonanatomic teeth have been used, two series of knives are cut into the posterior teeth by grooving into the porcelain, but leaving part of the original carbon marks in the cutting blades. The maxillary set of blades runs buccolingually, while the mandibular set runs mesiodistally to produce efficient cutting surfaces. The blades should have no more area than is needed to shred food, except that the fragility of tooth material requires some bulk for strength. Here is where our ingenuity reassembles nature's shredding actions to suit the conditions her malformations have given us. Frequently, the need for maintaining balancing contact over a long protrusive range compels the use of cuspal slopes which are two or three times the length provided by nature

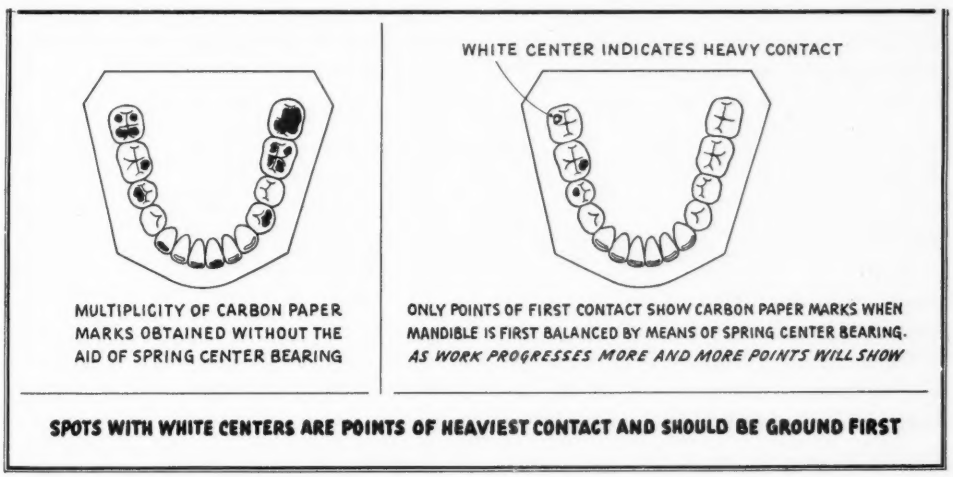

WHITE CENTER INDICATES HEAVY CONTACT
MULTIPLICITY OF CARBON PAPER MARKS OBTAINED WITHOUT THE AID OF SPRING CENTER BEARING
ONLY POINTS OF FIRST CONTACT SHOW CARBON PAPER MARKS WHEN MANDIBLE IS FIRST BALANCED BY MEANS OF SPRING CENTER BEARING.
AS WORK PROGRESSES MORE AND MORE POINTS WILL SHOW
SPOTS WITH WHITE CENTERS ARE POINTS OF HEAVIEST CONTACT AND SHOULD BE GROUND FIRST

Fig. 20.—Help obtained by use of a resilient central-bearing point. (Reprinted from the *Journal of the Southern California State Dental Association.)*

for balancing ideal dentitions with short vertical and horizontal overlaps. Properly harmonized and refined mechanical teeth are adaptable to provide the extra long posterior inclines which are needed to balance an extra long maxillary horizontal overlap. The basic design of ideal dentitions is traced by nature in the length and direction of mandibular movements. For this reason, all natural or artificial teeth should be formed to meet the conditions imposed by the relative sizes of the two jaws, by the mandibular rotation centers and paths, and by tooth locations. Therefore, necessary variations in tooth forms from ideal natural types are not a compromise, but are a development in harmony. When improper skeletal development changes the style in jaws, it is necessary to follow suit with new adaptations and harmonious styles in teeth. Nature's usual forms in teeth may no longer fit the problem.

Orton and Lischer[6] reported their observations on 2,982 college students. Of these, only 5 per cent possessed dentitions accepted as normal. None were ideal, although eleven approached an ideal development. The majority of this pitifully small number showed anterior tooth interference. For an explanation of why such a situation exists read *Nutrition and Physical Degeneration* by Price.[2]

The width of teeth is commonly thought to govern occlusal force, but the amount of actual contact between arches and the adequacy of escapeways is more important. That is the reason that all cutting surfaces should be narrowed to a fine line of carbon marking and deep grooves should be provided for the escape of shredded particles, regardless of the occlusal design in hand. Confined food needs much force to crush it, but finely cut material moving away through open channels requires comparatively little force. Incisal surfaces are ideally narrowed on the lower denture, but the upper incisive edges or inclines are best left broad for protrusive balance. Only the lower teeth need be sharp to incise food which is held against the upper teeth in the manner of a bread knife cutting on a board. Edges should be rounded to prevent chipping, and all sharp points should be polished.

"To cusp or not to cusp; that is the question. Whether 'tis better in the mouth to muffle the clacking rows of porcelain, or to take arms against a sea of troubles. And, by planning, end them. To ache and burn no more; and, by our skill, to know we end the ailments and the thousand painful shocks the mouth is heir to . . . 'tis a consummation devoutly to be wished; to eat, in comfort."

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THE ELUSIVE OBJECTIVES IN COMPLETE DENTURE PROSTHESIS

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PROSTHODONTISTS are in general agreement as to the requisite qualities of an acceptable prosthetic denture. In so far as conditions permit, it must be comfortable, efficient, and of pleasing appearance. We might well add a fourth requisite; i.e., the patient should be happy with the results of our efforts.

If there is a lack of agreement, it concerns the procedures involved in our attempts to attain these objectives. Through the years there have been numerous lectures and clinics in which various instruments, materials, and techniques were exploited and were suggested as offering maximum possibilities in the attainment of these objectives. The many and diversified procedures suggested as solutions to the problems of complete denture prosthesis may be interpreted as indicating a greater disagreement than really exists.

We have been so completely occupied in attempting to adapt various mathematical formulas and geometric patterns to our denture problems that we have given secondary consideration to factors which are now recognized as contributing greatly to a satisfactory prosthetic denture service.

At this very meeting we will see the results of various techniques and various instruments, all seemingly different and all apparently producing a satisfactory result within the limits of mechanical possibilities.* Those of us who are concerned with dental education at the graduate and postgraduate, as well as the undergraduate, levels have long recognized the desirability of agreement upon certain factors which might be set up as fundamental requisites to acceptable prosthetic denture service. The apparent lack of agreement upon certain of these principles may be the result of our failure to appreciate the distinction between principles and techniques.

It is not my purpose in this paper to present a definite technique for attaining successful results in any of the various phases of denture prosthesis, but rather to place emphasis on the contention that successful denture service is primarily the result of adherence to fundamental principles and secondarily the application and interpretation of these principles in various techniques and materials. It is suggested that some of the elusive objectives in our work are elusive because we fail to recognize the violation of certain of these principles in some phase or phases of our efforts. I should like to present what are, in my opinion, some of the areas in which the desired objectives are particularly elusive, together with a few suggestions regarding their attainment.

Read before the Academy of Denture Prosthetics, Bethesda, Md., May 2, 1951.
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*Ten different techniques were used by ten clinicians who constructed dentures for patients at the 1951 meeting of the Academy of Denture Prosthetics. Ed.

THE PSYCHOLOGIC PREPARATION OF THE PATIENT FOR PROSTHETIC SERVICE

This is one of the most important and probably one of the most neglected steps in the application of our professional services. We should not confuse psychologic preparation with the offering of excuses for faulty treatment, but we can and should take sufficient time to discuss with the patient the special problems in connection with his case, the possibilities and limitations; in short, what he may and what he may not expect.

There are many patients who will never be happy with prosthetic dentures regardless of the skill of the dentist who builds them. I quite agree with De Van[1] who wrote, "The satisfaction that a patient feels for the service of the denture specialist is often due more to psychologic factors than to physical. Complete dentures have foundational limitations that no prosthetic skill and good judgment can overcome."

Explanations regarding difficult conditions are much better received by the patient if they are offered before rather than after treatment.

Swenson[2] says, "The patient with whom a dentist is most likely to succeed is the patient with the proper attitude toward dentures." The proper attitude if not an optimistic one should at least embody an appreciation of the varied possibilities regarding probable results in different cases. We often overlook untoward factors in our original examination of the patient, only to discover them later during the treatment period. Certainly the earlier these conditions are discovered the better, and right then is the time to discuss them with the patient, with the adoption of a firm, sympathetic attitude designed to inspire confidence and cooperation. Happy denture patients are often the result of who does the work rather than what is done.

TISSUE TOLERANCE

The denture-supporting tissues were not designed by nature to be subjected to the stresses incidental to prosthetic restorations. Their reactions are variable and, to a great extent, unpredictable. The factors of tissue tolerance and mental tolerance seem to be closely associated. We may erroneously conclude that the pain of which the patient complains is more imaginary than real. The high-strung, nervous patient bumps into a door or piece of furniture and comes up with an ecchymosis and irritation, while the easygoing, more phlegmatic type may undergo a similar experience with no ill effects.

We see somewhat comparable conditions in denture patients; similarly extended dentures produce irritation in some mouths and no discomfort in others. Some of these patients are best advised to remove the dentures before retiring. There is evidence of improved tissue tolerance following treatment of known systemic disorders and correction of nutritional defects.

IMPRESSION PROCEDURES

Someone has truthfully said that the most important step in the construction of a denture is the one upon which we are working. While it is sometimes possible

to make a satisfactory denture from a faulty impression, we cannot depend on it. The ill effects of faulty adaptation are occasionally partially neutralized by the charitable processes of nature when assisted by a harmonious occlusion.

Fortunately, 50 per cent or more of our cases can be satisfactorily handled with almost any impression procedure which will reproduce the form of the denture-supporting area with a fair degree of accuracy. A large section of the remaining 50 per cent requires some manipulation of the readily displaceable tissue areas. The question of pressure versus nonpressure methods has been much discussed.

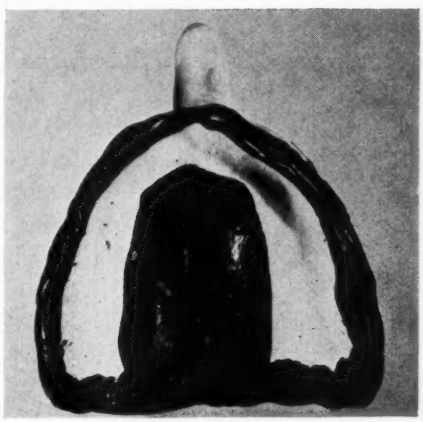

Fig. 1.

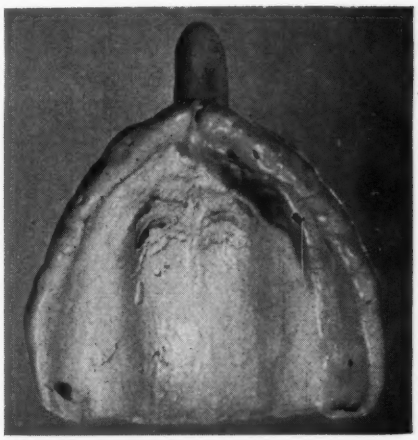

Fig. 2.

Fig. 1.—Tray constructed of self-curing resin over a cast made from a preliminary impression. The illustration shows border molding with compound tracing sticks. Note that the residual areas of the tray are out of contact with the tissues, permitting the recording of these areas without tissue displacement.

Fig. 2.—First wash taken in a soft flowing essential-oil paste. Note that in certain areas the tray material shows through the wash. These areas are scraped or relieved preparatory to taking the second wash impression.

Whenever pressure is employed in making the impression, there will be some tissue displacement if the tissue is displaceable by the force used in seating the impression material. An ideal impression is not necessarily a record of all areas of the denture-supporting tissues in their static form. The post dam represents an area of gentle tissue displacement. The tissues under the peripheral margins of the denture base will tolerate a slight displacement without inducing trauma or atrophy and without interfering with retention and stability. This displacement should not be of such an extent that there is a distortion of the muscle and frena attachments.

The best results are obtained if our impressions faithfully record the minute surface anatomy of the palatal and residual ridge areas, and, of course, this quality should be reproduced in cast. In my hands, this is most readily accomplished by the use of a plaster compound or one of the hard-setting oil pastes for the final impression. The use of waxes and the heavy gummy pastes is discouraged because of the difficulty in reproducing an accurate record in the cast, even if it were possible to obtain it in the impression. The residual ridges represent the areas where special care should be taken to avoid displacement. Patients sometimes

complain of the sensation of a void in the anterior palatal area under their dentures. This may be caused by tissue displacement in the impression process.

MAXILLOMANDIBULAR RELATION RECORDS

Vertical dimension or denture space is the number one factor in connection with this phase of our work. Various formulas based on face measurements may be of arbitrary value, but are unreliable when used alone. Maximum comfort may require some sacrifice of esthetic values. The loss of the natural teeth creates some esthetic problems, the solution of which is not possible with prosthetic dentures.

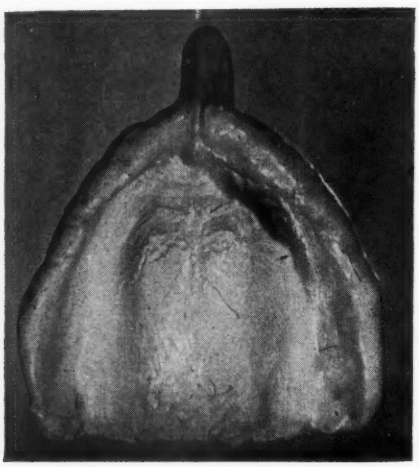

Fig. 3.—Final impression showing the elimination of pressure areas.

Successful practice demands that the vertical space occupied by the dentures represent a harmonious relation between the mandibular rest position and free-way space. We are not so much concerned with the question of constancy of the mandibular rest position throughout adult life as with the importance of the determination of this position at the time prosthetic treatment is instituted. The determination of an acceptable free-way space certainly represents an elusive objective. It cannot be determined by a fixed measurement formula. The free-way space varies within the limits of 2 to 15 mm. or more in different patients, and the variation may be almost as great in an individual patient, depending upon the age at which it is recorded and depending upon the nature of the changes which occur in the denture-supporting area.

Excessive abrasion of the teeth of individuals where there is little evidence of destructive changes in the supporting structures may be associated with a comparatively wide free-way space. The wide free-way space is also associated with certain types of malocclusion. Generally speaking, a minimum free-way space should be built into a prosthetic denture for a young patient, or one representing minimum changes in the alveolar structures. A maximum free-way space should be incorporated in the restoration for the patient of advancing years, or one representing maximum changes in the alveolar structures.

The use of so-called "bite-raising" restorations, in an attempt to correct auditory deficiencies or temporomandibular discomforts, is of questionable value in a high percentage of cases and is contraindicated in cases where their use would interfere with the establishment of a free-way space which could be regarded as normal for the individual under treatment.

The technique employed in the registration of the centric and excentric relations should avoid the use of methods or materials which tend to displace or distort flabby or readily displaceable residual ridge tissues. In the recording of jaw relations, as in the making of impressions, the harmful effects of pressure are more likely to occur in the flabby ridge cases. This displacement may be so slight that it is very difficult to demonstrate in the completed denture. Centric registrations made under pressure may induce premature contacts in the finished denture. This error is often improperly charged to the carelessness of the technician. Excentric registrations made under pressure will result in a condylar inclination which differs from one made with a minimum of pressure. The so-called built-in record of functional stresses is really a built-in record of tissue displacement which may result in occlusal disharmonies.

PROSTHETIC TOOTH FORM AND OCCLUSION

For maximum masticatory effectiveness, prosthetic teeth should be so formed and so positioned that when the jaws are in excentric relation and the teeth are in contact on the balancing side, there will be space for food between the upper and lower series on the working side. Except in unusually favorable cases, prosthetic dentures are ineffective as food grinders until the maxillary and mandibular dentures make contact. The grinding effect is operative from the time the teeth make contact in the excentric position until the chewing stroke terminates in centric occlusion. Evaluated from a mechanical viewpoint, the masticatory efficiency of the dentures will be in proportion to the effectiveness of the following factors: (1) occlusal balance and harmony, (2) available space for food between the upper and lower series of teeth on the working side, and (3) occlusal tooth forms which simulate cusp height and sulci depth. Trauma and tissue changes in the denture-supporting area are minimized in inverse proportion to the extent of the stress necessary to properly masticate the food. It seems logical to conclude that less stress would be required in mastication with the use of teeth with occlusal patterns developed to imitate the high sharp cusps and deep sulci of young natural teeth, provided they are positioned in functional balance.

While it is possible to position nonanatomic teeth so that the effect of cusp height, food space on the working side, and functional balance are obtained, it is difficult to contemplate masticatory efficiency comparable to that possible with natural tooth forms and with a similar degree of stress. Schuyler[8] writes, "It is extremely difficult to visualize a greater degree of oral comfort, functional efficiency, or a longer period of usefulness with dentures made using any of the many nonanatomic tooth forms, than by the use of the anatomic tooth modified and arranged to a functional balance, using the same favorable incisal guidance as would be used with the nonanatomic tooth, with the possible exception of the

case with an unusual ridge relation which necessitates a cross-bite or other abnormal positioning of the teeth."

The effectiveness of any tooth, anatomic or nonanatomic, in preventing trauma, irritation, and tissue changes in the denture-supporting area is dependent upon its being positioned in such a manner that the occlusion will be in harmony with jaw movements and position. This occlusal harmony may be accomplished by using either type of tooth; conversely, either type may be in disharmony. It is difficult to reconcile the factors of tissue resorption and occlusal disharmony. Either may induce a predisposition to the other. It suggests the question, "Which came first—the chicken or the egg?"

There is a certain amount of tissue change following denture restoration in nearly all cases. Is it not possible that there are indications for both types of teeth? The reference concerns cases of immediate replacement or other conditions involving obvious morphologic instability of the denture-supporting tissues and cases of pronounced malrelation of the ridges. The term, "balanced occlusion," is frequently employed, and various interpretations are implied. It is suggested that the term be interpreted as indicating a simultaneous contact at widely separated points, on either side, and anteriorly, when the upper and lower series of teeth are brought together and before they are subjected to heavy masticatory pressure.

The damage incidental to occlusal imbalance is affected during the interval between the instant the teeth first make contact and the time when they are subjected to the stress of the masticatory stroke. Some unavoidable tissue displacement in making the maxillomandibular records, together with dimensional distortion in denture base materials, may necessitate some final adjustment of the occlusion in the mouth. This is a somewhat elusive objective. The chair is elevated so the plane of occlusion is about level with the operator's eyes, and the patient is instructed *slowly* to bring the teeth into very light contact. As he does this he is asked to point out, with his finger, the areas of interference. This will locate the approximate points of premature contact. These areas can then be more accurately pinpointed by using very thin articulating paper and very light pressure, together with visual observation.

ESTHETIC REFINEMENTS

To be of maximum esthetic value, a denture must contribute to a pleasing facial composition as evaluated by the dentist, the patient, the patient's family, the bridge club, and sundry others among his or her associates. Many times the esthetic effect of an otherwise satisfactory denture is ruined by an ill-timed, uncomplimentary comment offered by one of the patient's friends.

The limitations of prosthetic dentures in the rehabilitation or maintenance of facial characteristics should seriously be considered by the dentist and appreciated by the patient. The loss of the natural teeth creates an esthetic problem, the complete solution of which is not possible with prosthetic substitutes.

As previously mentioned, satisfactory denture esthetics is only achieved in proportion as it is appreciated by the patient, and usually this objective is more nearly attained by attempting to recreate or maintain conditions which are normal

for the patient under treatment than by our efforts to substitute a classic or idealistic facial composition.

We have available today wonderful aids in the form of prosthetic teeth and denture base materials. These materials have induced some modification of our former concepts concerning the positioning of teeth and the modeling of the surrounding soft tissue substitute. The pleasing effect of the beautiful prosthetic tooth forms is partially neutralized by our failure in this connection. Pleasing

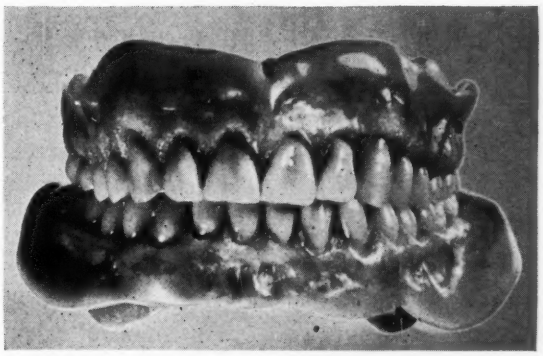

Fig. 4.—Completed dentures showing gingival conformation and characterization.

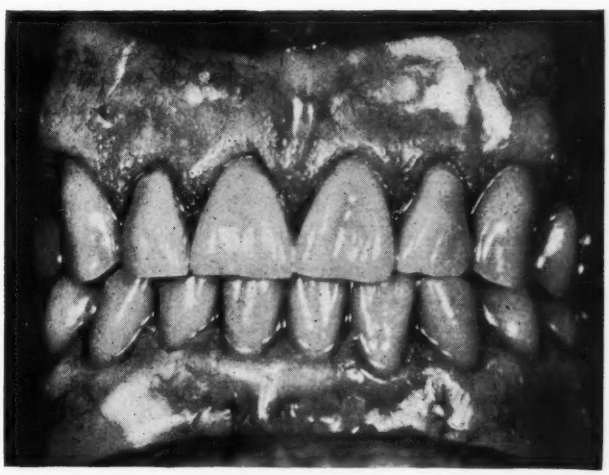

Fig. 5.—Close-up view of the completed dentures in the mouth. Note the natural-appearing gingival contours and shade variation.

effects in modeling the gums result from the blending of one surface into another, producing anatomic definition without excessive detail. The development of a series of parallel grooves between the tooth root areas should be avoided. To produce a realistic effect, the gum should contact the tooth to reproduce the free margin roll, rather than the common featheredge surface.

Emphasis should be placed on the importance of positioning the maxillary teeth in their normal relation to the lips and alveolar bone, rather than directly over the ridge. If, when a patient possessed the natural teeth, he normally displayed a broad expanse of gum tissue in talking or smiling, let him do so with the prosthetic denture so long as the substitute is modeled and tinted to simulate natural effects. For a pleasing natural appearance, the denture must be comfortable as influenced by bulk and free-way space. A more pleasing result is obtained by creating the effect of tooth form, tooth wear, and free-way space, representing the mature appearance common to people in the age group where prosthetic dentures are mostly indicated, than by propping the jaws apart with a heavy denture, using teeth of adolescent form and color in an attempt to create a youthful appearance.

CONCLUSION

Modern denture prosthesis contemplates a careful consideration of the foregoing principles, which have established themselves as being basic in nature, with additional emphasis on the factors of mental and tissue tolerance and the possibilities in connection with speech training and correction of nutritional disorders.

This short essay is offered, not with the intention of raising controversial issues or of challenging the use of any technique or materials, but rather to suggest the possibility that, despite our apparent disagreements, we may be approaching a more unified acceptance of principles which by reason of their wide acceptance and successful application may be regarded as being fundamental in nature and which may be applied while employing any of many different techniques, instruments, and materials.

Although there have been disagreements, controversies, and some confusion, it has been pleasing to observe the gradual improvement that has been made in the quality of prosthetic service offered by the average dentist in general practice. Successful denture prosthesis embodies the loftiest attainments in professional skill and represents the one specific treatment for many dental defects.

The requisite qualifications for excellent prosthetic denture services are well within the limits of those possessed by the dentist of average skill, and justifiable fees for this service are within the economic limits of patients in the average income group. The elusive objectives become decreasingly elusive as these fundamental principles are applied, and both dentist and patient appreciate the problems involved. No other branch of dentistry offers a greater challenge or affords a better opportunity for making patients healthier, happier, and more appreciative of our professional efforts.

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INARTICULATION OF COMPLETE DENTURES PROCESSED BY THE COMPRESSION MOLDING TECHNIQUE

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THE compression molding technique of processing complete dentures in acrylic resin has been used in dentistry since 1937. In the hands of a competent operator, this technique can produce adequate results with respect to both tissue and occlusal fit. Like many techniques in dentistry, however, the personal skill of the operator is an important criterion for a successful reproduction of the wax pattern. Coupled with this restriction is the invariable presence of a shifting of the teeth from their waxed-up positions. The manifestation of this tooth shift is an opening of the vertical dimension, and it is indicated by a raising of the incisal guide pin when the casts are remounted on the articulator. Compensation is made for this open vertical dimension by grinding the teeth until the original occlusion is restored. This grinding process not only absorbs valuable time, but in the case of more severe openings, necessitates a grinding of the teeth below the cusps, thereby eliminating the anatomic features of the teeth. A survey conducted among the University of Michigan Dental School faculty, practicing dentists, and laboratory technicians revealed that the increase of vertical dimension, as indicated by the incisal guide pin, to a distance of from ½ to 1 mm. is about the average opening that can be expected. While a few cases experience very little increased vertical dimension after processing, more severe increases do occur, and 2 to 3 mm. have been cited as being experienced.

Although this increase of vertical dimension might appear quite severe, the actual amount of tooth shift needed to cause it is definitely of a lesser amount. If it is assumed that each denture, both upper and lower, is equally responsible, then a factor of 2 can be introduced. If consideration is given to the lever ratio which exists on the articulator from posterior to anterior and if the second molars are investigated, then another factor of 2 can be introduced. Therefore, a raising of the incisal guide pin or increased vertical dimension of 1 mm. can be the result of just a ¼ mm. (or 0.010 inch) tooth shift. This tooth shift, or change in vertical dimension, was reported recently by Steck,[1] and some of her results are confirmed by this investigation. Other authors[2, 3, 4] have also investigated this problem, but, to date, no solution has been reached.

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Since this process involves several kinds of materials which are subjected to pressure and thermal cycles, as well as changes of state, it is evident that there can be several factors, any or all of which may contribute to this difficulty. To arrive at an adequate solution to this problem, a complete analysis of each of these factors should be undertaken; the final conclusions will then be reflected in an integration of these individual results.

This report is concerned with the analysis of one of these factors which, in the author's opinion, is responsible for a greater portion of the difficulty. This factor is the vertical movement of the teeth relative to the investment, caused by the pressure applied by the acrylic resin during the packing and curing process. This approach to the problem is a direct result of the practical applications arising from a previous paper on hardness and flow properties of gypsum materials.[5]

The over-all procedure was, first, to determine the pressure applied by the acrylic resin; second, to determine the resistance of the investment to the subsequent tooth movement; and third, to correlate these determinations to the increase of vertical dimension as indicated by the raising of the incisal guide pin.

The requirements for pressure on the resin during the curing process consist of an adequate filling of the mold and a slight positive pressure during processing to avoid porosity in the denture. Despite these rather simple requirements, there are many factors which can influence this pressure and which must be controlled in order to control the pressure effectively. They are listed below along with the measures used to control them in the tests conducted in this project.

1. The force applied to the flask during the packing process. This force was applied with an hydraulic press having an indicating gauge which measured the force. This force was maintained for one hour, after which the case was placed in a curing bath for one and one-half hours at 160° F. and one and one-half hours at 212° F.

2. The amount of acrylic resin in the denture cavity in excess of the exact amount needed when the above force was applied. A specific amount of material was mixed, and the case was trial packed until the flask was open a given distance. Trial closure was subsequently made at a given pressure.

3. The workability or viscosity of the resin at the time of packing and final closure. The powder-liquid ratio of the resin was kept constant, as well as the mix temperature and time interval from the initial mixing to the trial-packing stage and the final closure stage.

4. The shape of the denture. This was kept constant by methods described later on in this paper.

5. The effect of the thermal cycle. Flasks were cured under spring tension to avoid these effects.

By controlling these factors, therefore, the pressure in the resin can be kept constant or varied. The most expeditious means of varying the pressure was found to be a regulation of the amount of opening of the flask before final closure and adjustment of the force on the flask to achieve closure. The remaining factors were kept constant at all times.

The next step in the procedure was to measure this pressure quantitatively. In Fig. 1 is indicated the method devised to achieve this purpose. It consists essentially of a denture baseplate of one wax thickness onto which have been set three steel balls, one-half inch in diameter, ground in half. A double thickness of wax was used under the balls. The model used was duplicated from a V-B-M mold so that the denture shape remained constant. The cast was invested in a three-section gypsum mold. Dental plaster was used in the first and second pour or section, and dental stone was used in the third pour or section. The third section is commonly called the splint because of its restraining action on the teeth. Wax forms were placed on the balls before the second

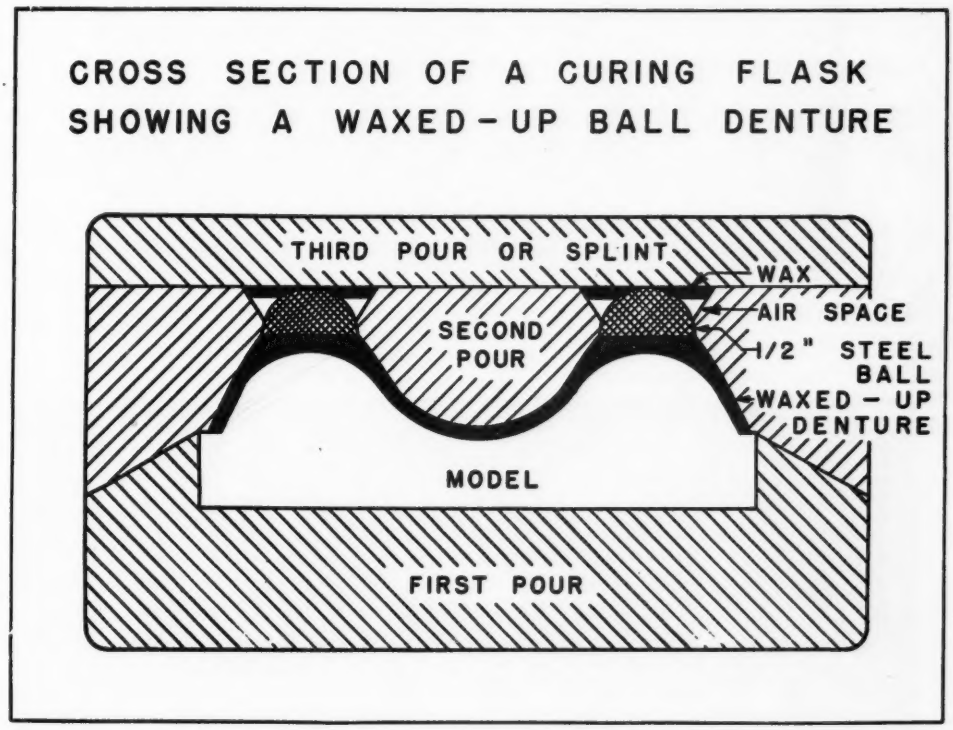

Fig. 1.

pour was made to allow an air space, as indicated on the drawing. In this manner, the balls were allowed to move under pressure from the acrylic resin with a minimum of restriction from the second pour. After the second pour was made, these wax forms were removed, and a wax filler was melted into position to prevent the third pour, or splint, from filling up the air space. The denture was then processed in acrylic resin of the powder-liquid form.

Essentially, then, there existed a situation in which the pressure in the resin was applied to a one-half inch steel ball which acted as an indenter and was restricted in its movement by the material used in the third pour. In Fig. 2 is a picture of the indentations made by this device in the third pour of investment after processing. These indentations were measured diametrically using a com-

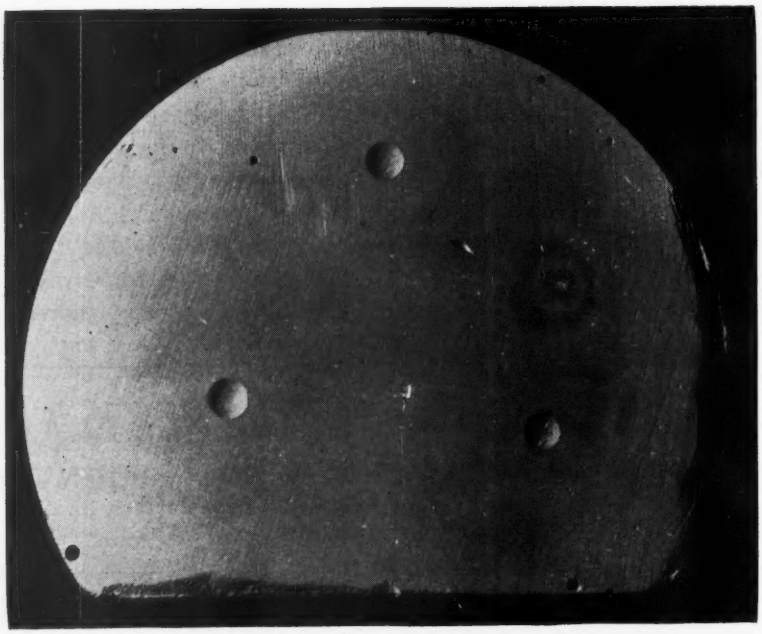

Fig. 2.

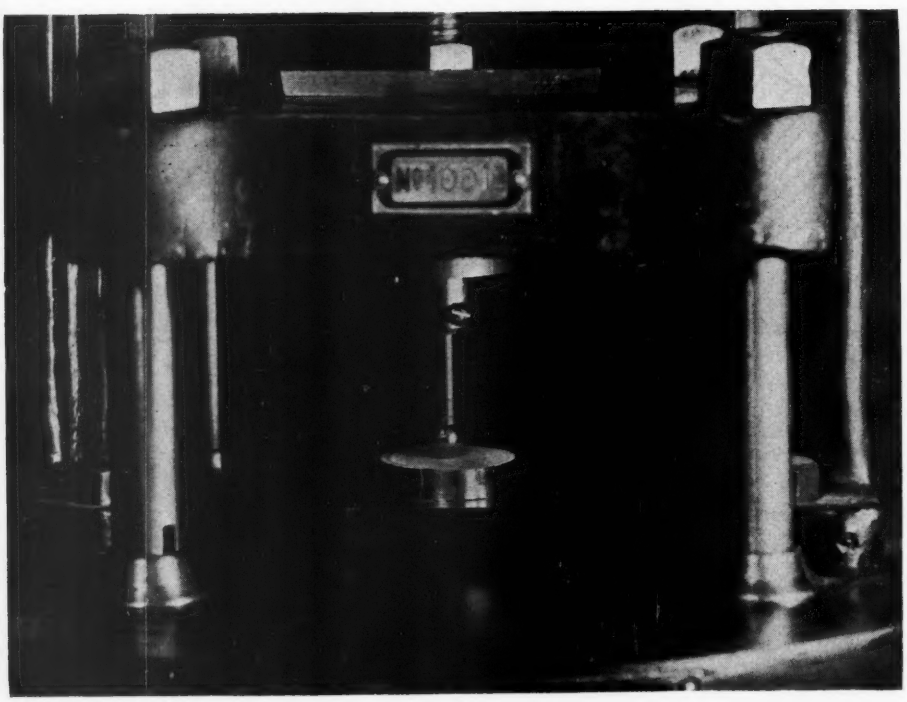

Fig. 3.

parator microscope. An interesting development at this point was a comparison with several early tests which showed different-sized indentations in the same splint. This indicated the presence of unequal pressures in the resin. This difficulty was eliminated easily by exercising care in trial packing so the acrylic resin was evenly distributed and the flask closed uniformly. However, the observance of a possible unequal pressure distribution indicated that the acrylic resin has sufficient shearing resistance or viscosity to allow severe stress distributions in the measured resin. As a result, it is possible to get more tooth shift on one side of the denture than on the other.

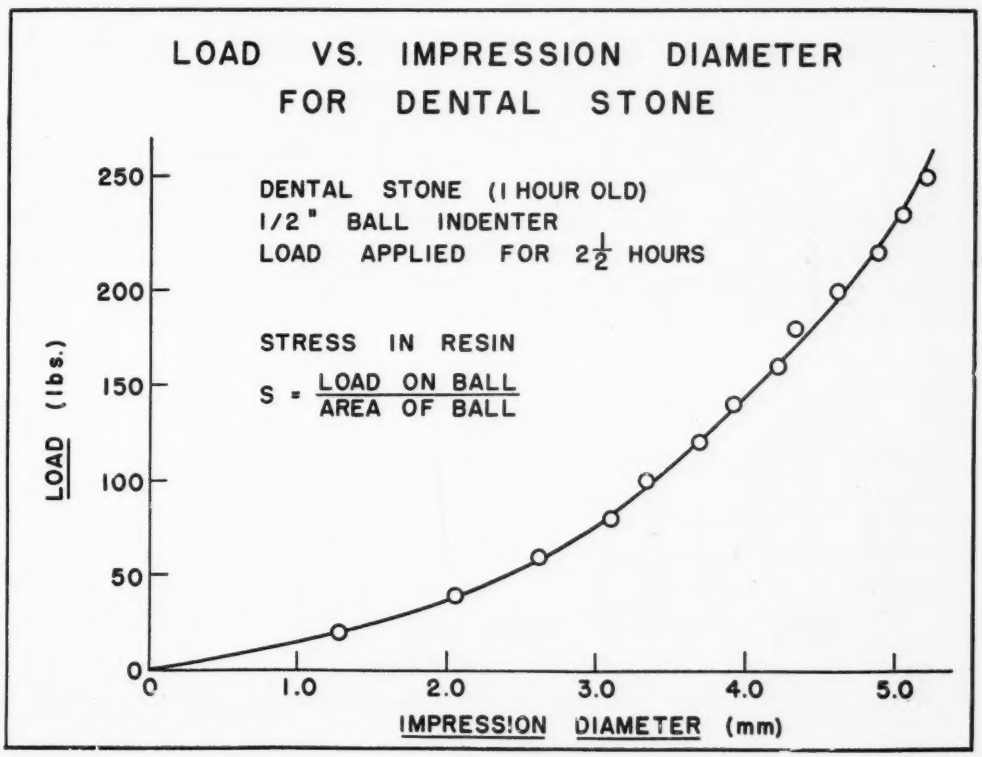

Fig. 4.

In Fig. 3 is shown the same condition which exists in the flask, duplicated on the bench. A one-half inch steel ball was mounted in a Tinius Olsen universal testing machine, and different loads were allowed to indent a specimen of gypsum material similar in condition to the third pour in the flask. These indentations were then measured, and a calibration curve was plotted which is shown in Fig. 4. The procedure to determine the pressure in the acrylic resin for a given packing condition is then reduced to the following. From the curve in Fig. 4, the load needed to produce any size indentation is known. For a given packing condition, the third pour will experience a specific set of indentations. The average measurement of these indentations is then referred to the curve where a corresponding load is determined. This load must then be the one which the resin applies to

the steel balls. Since the area of the steel balls is known, the pressure in the resin is simply this load divided by the area of the steel ball.

The resistance of the material in the third pour to this indentation was the next major consideration in the over-all analysis. This was easily varied by the use of three different third-pour materials (plaster, stone, or improved stone). For each, it was possible to maintain constant properties by using any of these materials under the same manipulative and storage conditions. Tests of the hardness and flow properties of these materials, as reported previously,[5] define the property of resistance to indentation for these gypsum products.

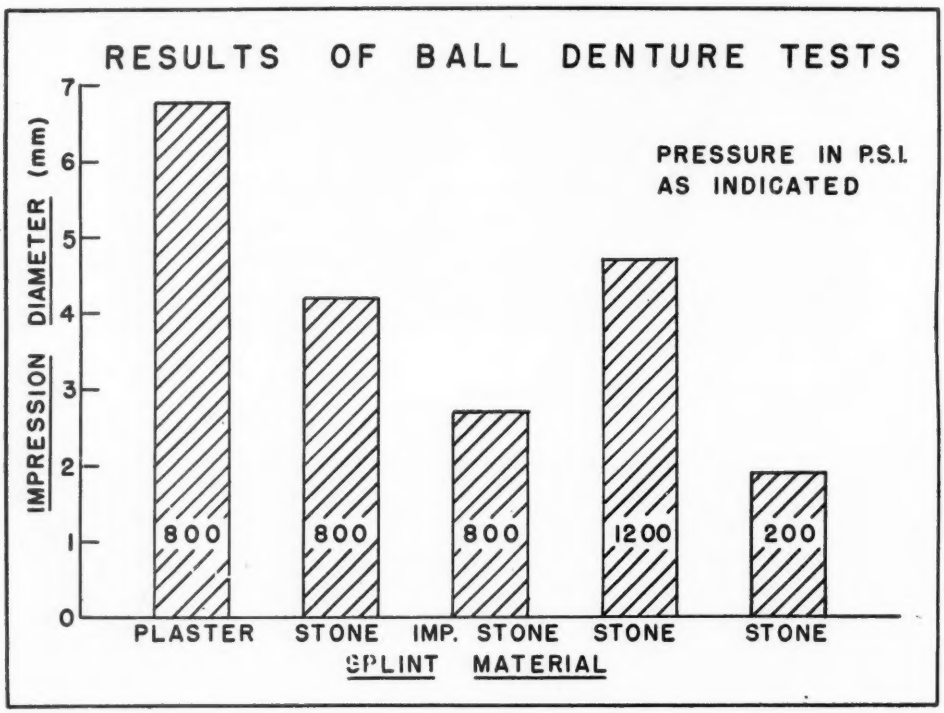

Fig. 5.

In Fig. 5 is shown the effect of pressure applied and resistance of material to indentation on the diameter of impression as evidenced by the indentations in the third-pour material. As can be seen, the higher the pressure and the weaker the gypsum material, the larger the indentation. The 800 pounds per square inch in the acrylic resin represents a packing and curing condition which was ascertained by having several dentists and a laboratory technician process these "ball dentures." This pressure corresponded to a load of about 5,000 pounds on the flask at final closure. The 1,200 pounds per square inch was achieved by trial packing until the flask was open 0.030 inch (about 1/32 of an inch), for which 8,000 pounds were then necessary to achieve closure. The 200 pounds per square inch was the minimum pressure, from a practical standpoint, that could be applied and still achieve flask closure with the acrylic resin used. This pressure

corresponded to a load of 1,500 pounds applied at final closure after several trial packs. These three values, then, represent three categories of pressure which could be interpreted as an average pressure, an excessive pressure, and a minimum, or possibly an optimum, pressure.

One important point which might be introduced here is the capability of the present dental presses to apply these forces to the flask. A brass rod with attached strain gauges was placed in various dental presses; the strain was recorded when the press handles could not be turned manually any farther. These strains were then converted to stresses and loads, since the modulus of elasticity and area of the brass rod were known. The following table indicates the maximum forces that can be administered by the different types of presses:

Type of Press	Maximum Force (Pounds)
Curing press (4½ inch handle)	5000
Bench press (5 inch handle)	4500
Bench press (9 inch handle)	8000
Hydraulic press	Over 10,000

These values are for those presses which were available at the time and will vary according to the make and model of the press, since the size of the actuating screw is as important as the length of the handle in determining the maximum force which can be applied. From these values it is apparent that the average dental press is capable of applying enough force to the flask to place an excessive pressure on the resin. It is important to emphasize, for the sake of clarity, that the force on the flask during closure is a separate and distinct entity from the pressure in the resin mass. This force is only one of the factors which influence the pressure in the resin.

At this point in the study, the pressure in the acrylic resin and the resistance to indentation had been determined and could be measured and varied as independent variables. The next step was to determine their effect on the increased vertical dimension of complete dentures as measured on the articulator.

Similar casts were used for the complete dentures as for the ball dentures, and a complete case with the full complement of teeth was processed. The resulting dentures were then duplicated each time by a method described elsewhere.[6] A V-B-M mold was used so that the shape factor was kept constant. The waxed-up models were articulated and then positioned on a Hanau articulator. Dental plaster was placed between the models and a keyed mounting on the articulator. When the dental plaster was set, the casts were removed and processed. The first and second pours used were also made of dental plaster. Subsequent to this procedure, the casts with dentures still attached were remounted on the articulator, and the increase of vertical dimension was measured (using feeler gauges) as the distance the incisal guide pin had been lifted from its original position.

It is important to indicate at this time that the packing and curing procedure used for the complete dentures was exactly the same as used for the ball dentures (for which pressure measurements had previously been made). In this manner, the pressure in the resin for the processing of the complete dentures was established.

The correlation between the two variables of pressure and resistance to indentation on the open-bite measurement observed is shown in Fig. 6. For the average pressure of 800 pounds per square inch, the amount of increase of vertical dimension decreases as the splint or third-pour material is changed from dental plaster to dental stone, or to improved dental stone. With dental stone in the splint, the excessive pressure of 1,200 pounds per square inch yields almost twice the increase of vertical dimension present at the optimum pressure of 200 pounds per square inch. This emphasizes the need for minimum pressures during flask

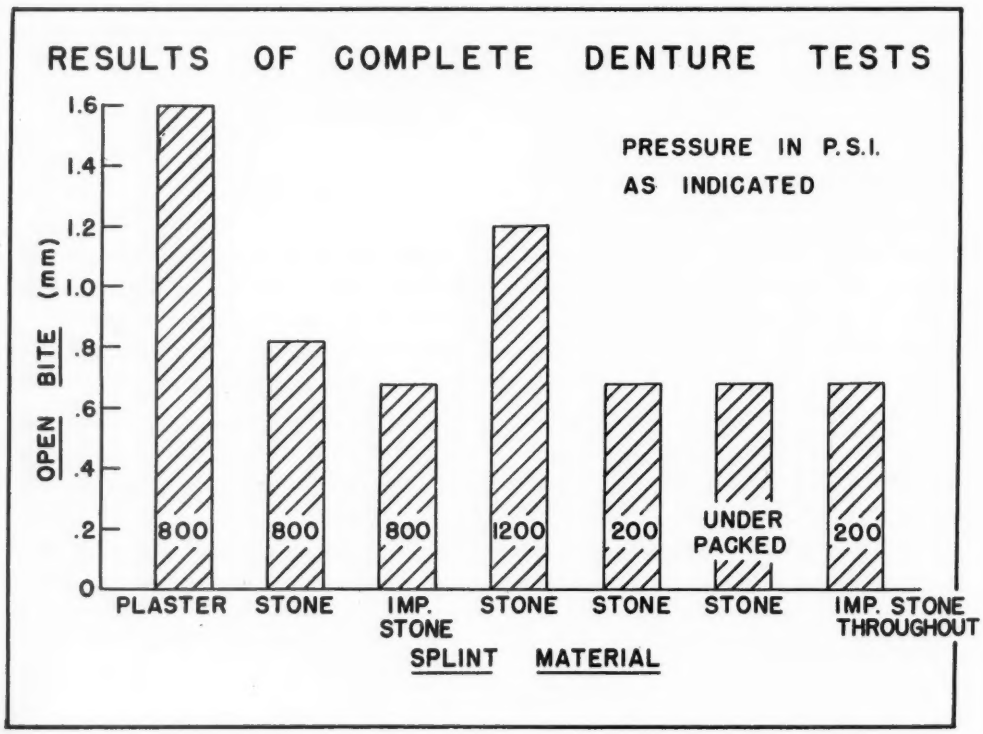

Fig. 6.

closure. An underpacked case and one which utilized the improved stone throughout the flask are also shown on this graph. It is interesting to note, by considerations of pressure in excess of 200 pounds per square inch and the resistance to indentation properties of the gypsum materials used, that there appears to be a minimum to which the increased vertical dimension can be reduced. As previously mentioned, it appears that other factors must be investigated before this increased vertical dimension can be reduced any farther.

CONCLUSIONS

The following conclusions were determined by this study:

1. A method of measuring the pressure in the acrylic resin during the packing and curing process was established.

2. Acrylic resin, at the final closure of the flask, has sufficient internal shear resistance or viscosity to allow severe stress distributions in the uncured denture. The practical manifestation of this unequal stress condition is a shifting of some teeth more than others.

3. Increased vertical dimension to a minimum limit of 0.6 mm. under the experimental conditions described was found to depend on the pressure in the acrylic resin.

4. Increased vertical dimension to a minimum limit of 0.6 mm. was found to depend on the material used in the splint, or third pour, of the flask.

5. At relatively low pressures, an underpacked case showed no decrease in the amount of increase of vertical dimension, indicating that an absence of pressure during the curing cycle had no effect upon the vertical dimension measurement.

6. At relatively low pressures, a denture flask packed entirely of improved dental stone showed no inclination to reduce the minimum increase of the vertical dimension measurement. This would tend to minimize any effects offered by the first or second pour of investment.

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AN EVALUATION OF BASIC CONCEPTS IN MOUTH REHABILITATION

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MOUTH rehabilitation has definitely come of age. It is no longer condemned as a pretentious young upstart inevitably doomed to failure and ruin. It now only receives an admonishing finger to be very careful and very discreet. However, much contention exists as to the proper approach to this problem. Essentially there are two philosophies, or schools of thought, in this important field of restorative dentistry which are diametrically opposed to each other. One is the McCollum school, and the other may be designated the "biomechanical school." Before an attempt is made to evaluate these opposed concepts, certain fundamental definitions, dental truths, research findings, and histologic facts must be established.

PHYSIOLOGIC OCCLUSION

Definition.—Box[1] has defined physiologic occlusion as "a condition in which the system of forces acting upon the teeth during function are in a state of equilibrium, and *do not* and *cannot* change the normal relationship existing between the teeth and their supporting structures."

The Optimum Occlusion for All Dentistry.—Thus, physiologic occlusion represents the ideal occlusal relationship which all fields of dentistry must seek to achieve to maintain periodontal health. This ideal relationship is but rarely found in modern man.

However, in adult natural dentures where we encounter mutilations and/or occlusal disharmony, we can, by correct mouth rehabilitation, achieve a physiologic occlusion in many cases and closely approximate this ideal in a great many more. Frequently, grinding and orthodontics are necessary adjuncts.

It is imperative to bear in mind that a physiologic occlusion is one in which the relation between the teeth and the periodontal tissues is such that under occlusal stress no injury is produced by them; and further, the tissues are best able to withstand the forces of occlusion without the initiation of pathologic changes in the periodontium.[1]

TRAUMATIC OCCLUSION

Definition.—The term "traumatic occlusion" was created by Stillman and introduced in 1917 into the current literature. Stillman and McCall defined

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traumatic occlusion as "an abnormal occlusal stress which is capable of producing, or has produced, injury to the periodontal tissues."[2]

Vertical and Horizontal Overloading.—According to Box, traumatic occlusion is manifested clinically in two forms, i.e., vertical and horizontal overloading.

Vertical overloading is where the applied occlusal force is exerted in the direction of the long axis of the tooth, and the tooth is subjected to intermittent pressure greater than it should be called upon to bear.

Horizontal overloading is exerted in a direction oblique to the long axis of the tooth and may be resolved into a vertical force acting along the axis and a horizontal one at right angles to it. This horizontal force enters into the production of an abnormal torque which creates overstress in the gingival third and the apical third of the periodontal membrane.[3]

OCCLUSION IN PRIMITIVE MAN

The research findings of Cameron, Stein, Campbell, Pleasure, Hanau, and others[4] indicate that in primitive man early wear of the teeth was the rule. Interfering cusps were quickly worn, and no individual loading was permitted with its sequelae of lost teeth. Although young specimens showed upper incisors overlapping the lower, adult specimens showed typical edge-to-edge bite. These findings served as corroborative evidence that normal attrition (with its accompanying reduction of horizontal loading) was consistent with sound, healthy dentitions in primitive peoples.[4]

GOTTLIEB'S THEORY OF CONTINUOUS ERUPTION AND COMPENSATING WEAR

Gottlieb[5] first introduced his theory of continuous eruption in 1932. Orban later corroborated and supplied additional proof of this theory in his histologic studies. Gottlieb specified the following processes as comprising the normal involution of the teeth:

1. Protrusion of the teeth toward the occlusal line—continuous eruption
2. Compensatory abrasion of the teeth both at the grinding surfaces and at the points of contact
3. Mesial displacement of the teeth
4. Atrophy of the alveolar crest
5. Migration of the epithelial attachment toward the apex.

To be within physiologic limits, the rate of continuous eruption must be slow so that the part of the tooth remaining invested in the alveolar bone (the clinical root) is at all times sufficiently long to support mastication. Also the abrasion of the chewing surfaces should keep pace with the downward growth of epithelium to prevent the extra-alveolar level (clinical crown) from becoming abnormally long.[5]

FUNCTION OF CUSPS

It would seem, therefore, that the function of the cusps is to guide the teeth into their correct positions in their early eruption to the occlusal plane and to maintain them in these positions until the bone is strong enough to assume this function without cusp aid.[6]

Attrition of the tooth surfaces, then, would appear to be the ideal regulator of the articulation as this method of adjustment is operative throughout the animal kingdom.

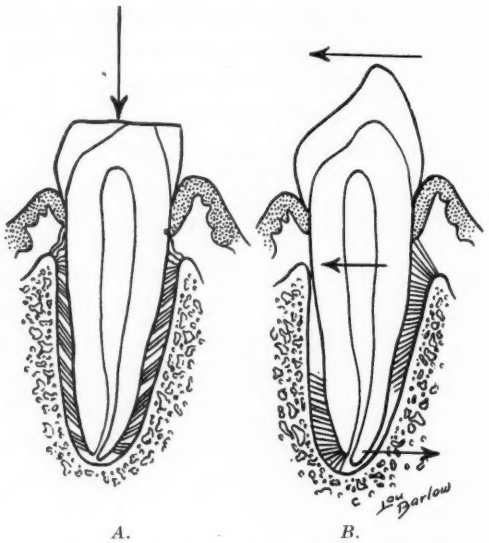

Fig. 1. — *A*, Vertical loading distributes stress over entire alveolus and may be increased considerably without overloading. *B*, Horizontal loading acts on the periodontal membrane and bone regionally and frequently exceeds the normal limits of the tissues. (After Kronfeld.)

Modern dentitions, generally speaking, show a retarded degree of occlusal wear in early adult life. This is the result of a decrease in the abrasive action due to modern diet and modern methods of cooking. An adjunct to supply this lack of abrasive action is indicated. Teeth with poor periodontal structures stand in special need of such an adjunct.

EFFECTS OF HEAVY FUNCTION

Both Box[7] and Kronfeld[8] have stated that when the cusps have been worn down enough to produce mostly an axial loading, the bone receives the stress more evenly over the entire alveolus. In consequence, heavy function (i.e., increased stress within the limits of the reserve force of the cell) tends to be beneficial and may be increased considerably without the danger of overloading. Thus, the greater the functional stress, the stronger and denser will be the supporting bone, and the greater the increase in the physiologic hypertrophy of the periodontal fibers (Fig. 1).

However, great increase in functional stress that acts on the tooth more or less horizontally and is sustained by the periodontal membrane and bone region-

ally instead of generally frequently exceeds the normal limits of the tissues and is not beneficial. On the contrary, changes take place that represent a reaction on the part of the tissues to injurious agencies. [7,8]

ARTICULATION VERSUS FUNCTIONAL OCCLUSAL HARMONY

The McCollum[9] school contends that correct tooth relationship can exist only where teeth are provided with anatomic, interdigitating cusps which are shaped and arranged for precise integration with the hinge axis, condyle path, lateral path, and Bennett movement. This school (The Gnathological Society of California) has developed a most ingenious recording device and articulator which traces and duplicates these jaw movements. This group maintains that only such anatomically perfect relationship of the teeth or articulation conforms to oral physiology and is, therefore, a prerequisite for maintaining dental health in any and all mouths.[9] In expounding this concept, one of its exponents concludes as follows: "When one sees rampant decay, and chronic gingivitis and bone destruction, and loosening abutments and dentures that won't stay put, and tender sore teeth, and obscure facial pains whose etiology does not seem clear, look first at the function of the whole mouth, not the local condition. Gradually, one will begin to get a different view of dentistry, a clear over-all picture of dental practice, of which this is the cornerstone, 'the practice of dentistry is the science of articulating teeth.' "[10]

The biomechanical school contends that the posterior teeth are closer to the action of the incisal inclination than they are to the condyle action; therefore, a greater influence is exerted on the teeth by the incisal inclination than by the condyle guidance.[11] And since the incisal guidance, the curve of Spee, and the plane of occlusion are largely under the dentist's control, the condyle movements do not dictate an anatomic, interdigitating cusp relationship. It maintains that functional occlusal harmony can be achieved with shallow modified cusps and that such an occlusal relationship is consonant with sound physiology. This school maintains that once the teeth have erupted to the occlusal plane, the persistence of cusps is neither necessary to an optimum occlusion nor to periodontal health, but that rather the contrary is true, that such cusps create greater oblique stresses and are, therefore, more likely to produce injurious reactions on the supporting structures.

Under like conditions, the teeth of young people will stand more stress than those of older people, the resistance and reparative powers of tissues being greatest in youth and thereafter decreasing gradually with advancing age. Hence, in youth, unfavorable stresses may well remain within the physiologic range, yet these same stresses may favor pathologic changes in the periodontal tissues in later years. Therefore, the shallow, modified cusp permits the most favorable occlusal relationship for achieving a physiologic occlusion as defined by Box.[12,13]

SPLINTING VERSUS PHYSIOLOGIC MOVEMENT OF TEETH

Disciples of the McCollum school have argued that splinting of teeth should be avoided as much as possible as it prevents the physiologic movement of the

individual teeth. This is to say that the lateral movement of the teeth in their sockets is desirable and essential to the health of the supporting structures.

This concept parallels the teachings of Herman Chayes who first introduced this idea. Chayes contended that the clasp appliance bound the tooth too rigidly and did not permit the tooth freedom of movement or normal stimulation essential to tissue health. He believed and taught that the precision attachment was superior because it did allow this freedom of tooth movement which he termed physiologic. Since then, clinical observation and histologic studies have established the superiority of the precision attachment as the most effective means of supporting a removable partial denture but for exactly the *reverse* reasons: that the clasp creates undesirable lateral stresses tending to overstress the tooth support, while the precision attachment ties the abutment teeth more rigidly together, directing the occlusal stresses in the more favorable vertical direction.[14]

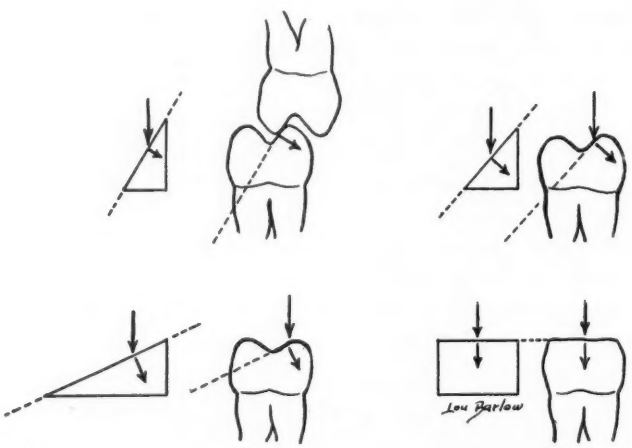

Fig. 2.—A comparative study of the resultant forces of inclines. The steeper the cusp, the greater the horizontal loading (resultant force). (After Swenson.)

Similarly, the splinting of teeth for abutment purposes or for reinforcing weakened or mobile teeth serves to dissipate the lateral stresses and reduce the individual loading of teeth by distributing the occlusal forces among all the teeth so united. Splinting lessens the possibility of overloading of individual teeth and is particularly indicated in mouth rehabilitation. True physiologic movement is not prevented thereby, since vertical loading is still possible, and such limitation of movement is not only adequate for cellular stimulation, but most desirable for maintaining health of the supporting structures.

CROWN-ROOT RATIO; BROAD OCCLUSAL TABLES; WARPED CUSPS

Exponents of the McCollum school argue that it is not necessary to maintain a favorable ratio between the clinical crown and clinical root, that where the teeth are articulated, the increased clinical crown creates increased function which stimulates cell metabolism. They offer similar argument in defense of broad

occlusal tables and warped cusps which they frequently find necessary to achieve articulation in their reconstructions.

The biomechanical school maintains that unfavorable ratios of clinical crown to clinical root, broad occlusal tables, and warped cusps are undesirable factors because they create stresses which are not in the direction of the long axis of the tooth and which tax the limits of the reserve forces of the cell; that such stresses tend to overstimulate the cell metabolism and induce cell destruction.

BIOMECHANICS

Both schools maintain that their approach to the problem of mouth rehabilitation or reconstruction is biomechanical. Both schools agree that all mechanical replacements must, in function, exert stresses of one type or another on their supporting and opposing structures and that the objective is to so construct and arrange the mechanics as to produce stresses most favorable to the physiologic maintenance of the periodontal tissues.

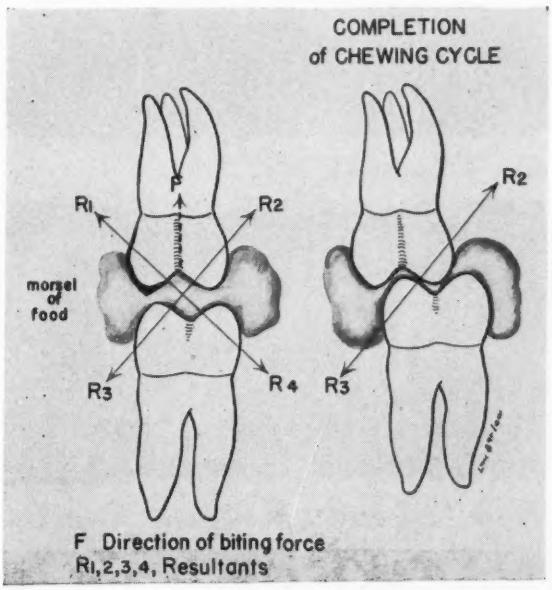

Fig. 3.—The direction of the forces acting upon the teeth during the chewing cycle. (After Pleasure.)

The McCollum school claims that: "anatomy is the dynamic form and relation of parts which makes physiology possible; that the functional forces involved in chewing with cusps are the true biologic factors because they are the functional demand which determines the metabolic requirement or the ability of the metabolic level to maintain the tissues of the mouth."[15] Therefore, mechanics constructed to such anatomy is biologic.

The opposing school argues that the tooth form must be interpreted in terms of the forces acting upon it. It is an axiom of physics that a force acting upon

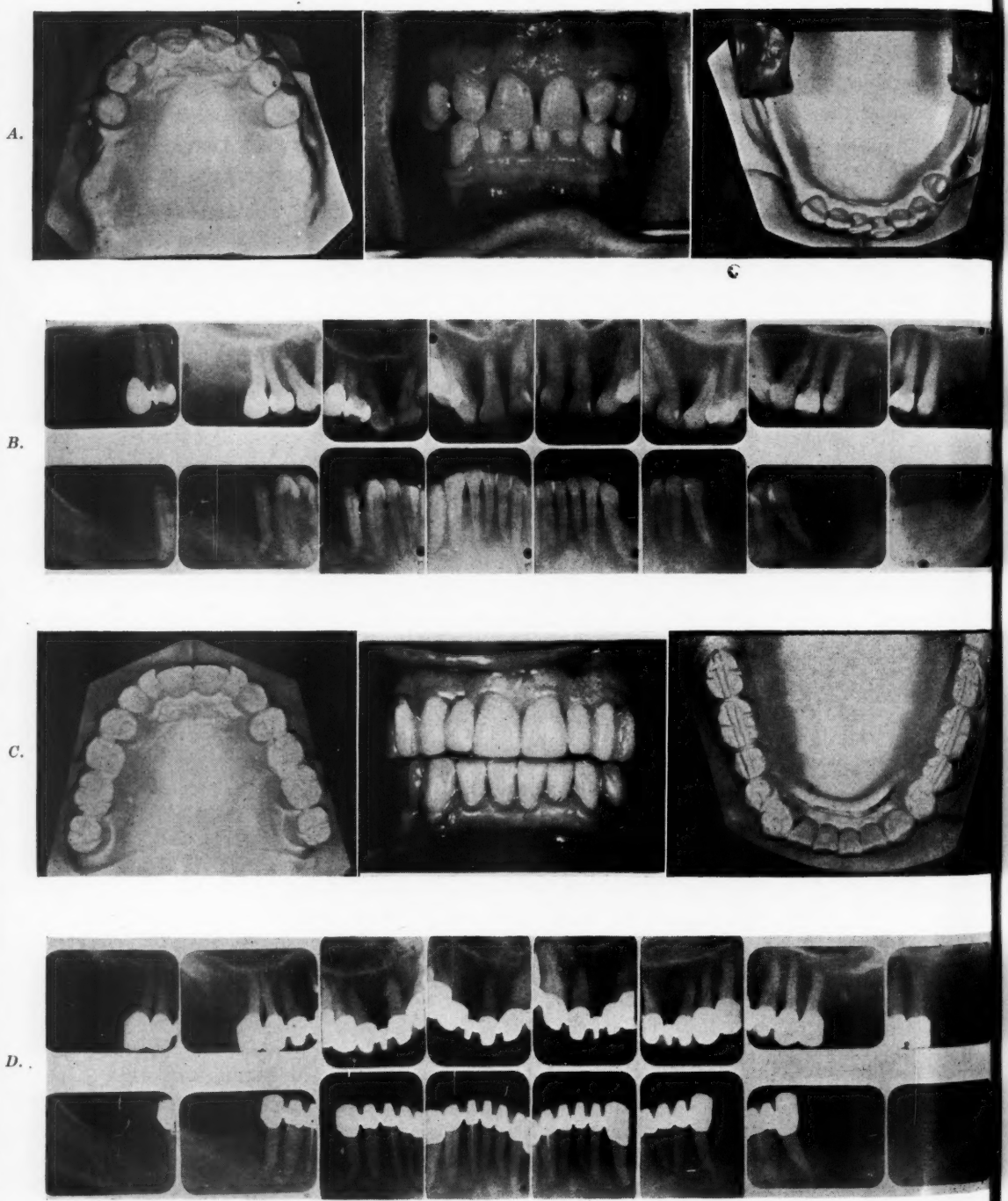

Fig. 4.—*(For legend see opposite page.)*

an inclined plane generates a resultant at right angles to the plane (Fig. 2). It is this resultant which constitutes the unfavorable horizontal loading. Thus, chewing with anatomic cusps can generate strains beyond the ability of the periodontal tissues to maintain health (Fig. 3).[16] Therefore, the biology of our mechanics must be evaluated in terms of the horizontal and vertical loading which is determined by the occlusal form and inclination of the tooth. Our mechanics should seek to eliminate all possible side movement of the teeth, directing the occlusal forces along the long axes of the teeth. This school maintains that the shallow, modified cusp, favorable crown-root ratio, narrow occlusal table, and splinting reduce the injurious oblique stresses and horizontal loading and are, therefore, in harmony with the biologic requirement. Clinical experience substantiates these concepts (Figs. 4 and 5).

CONCLUSIONS

1. The condyle path does not dictate the cusp form. The incisal guidance has a greater influence on cusp form.

2. The incisal guidance, curve of Spee, plane of occlusion, and inclination of cusps can be controlled to produce shallow cusps which are more favorable to the physiologic maintenance of the periodontal tissues.

3. An occlusion "geared" to the condyle movements is not necessarily physiologic as defined by Box.

4. The biology of our mechanics must be evaluated in terms of the horizontal and vertical loading of the teeth. Optimum loading necessitates shallow cusps, favorable crown-root ratios, and multiple splinting.

5. In aged mouths or where mutilations and periodontal breakdown are evident, the McCollum school's concepts of articulation, nonsplinting, broad occlusal tables, and warping of cusps can prove traumatic in effect and are, therefore, potentially pathogenic factors as applied to mouth rehabilitation.

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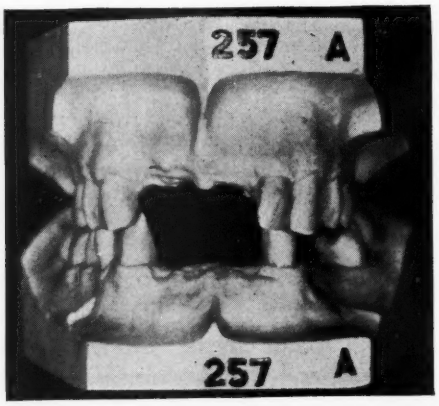
Fig. 4.—*A*, Case presenting marked loss of vertical dimension, mutilations, congenitally missing maxillary laterals, and retruded anteriors.

B, Radiographs of original condition.

C, Completed case. Orthodontic treatment was instituted to create a more favorable alignment of maxillary anteriors and to provide space for lateral incisors. All the remaining upper teeth were splinted together as were all the remaining lower teeth to provide maximum distribution of loading and resistance to torque. These stationary segments maintain the new vertical dimension. The plane of occlusion created provides for maximum occlusal contact in all functional excursions.

D, Radiographs one year after treatment (devitalization of lower left lateral necessitated by operative exposure during treatment).

A.



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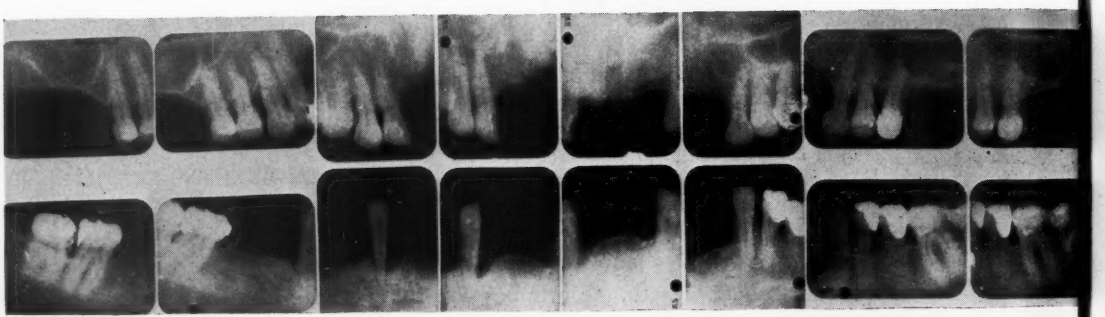

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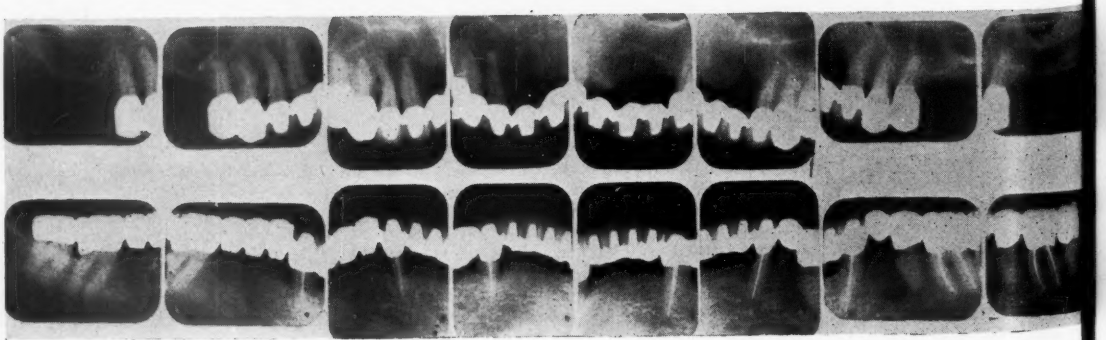

Fig. 5.—*(For legend see opposite page.)*

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Fig. 5.—*A* and *B*, Case presenting mutilations and periodontoclasia. The extensive and disproportionate loss of bone around the lower cuspids was due to marked overbite and horizontal overloading of these teeth.

C, Here the diagnosis and treatment plan required the devitalization of both lower cuspids to reduce the overbite, to create a more favorable crown-root ratio, and to bring these teeth into a plane of occlusion whereby they would receive optimum loading (vertical loading). All the lower teeth from right second molar to left third molar were splinted together in one unit to provide maximum distribution of loading and resistance to torque. For similar reasons the upper teeth from right second bicuspid to left second bicuspid were splinted together, and a precision partial denture was constructed to replace the missing posterior teeth. The vertical dimension and plane of occlusion established resulted in a marked overjet but in effect provided an end-to-end occlusion with maximum occlusal contact in all functional excursions.

D, Radiographs two years after treatment.

A FUNCTIONAL EVALUATION OF FIXED AND REMOVABLE BRIDGEWORK

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ONE objective of prosthetic procedures is to establish and to maintain a high functional capacity of the masticatory apparatus. It has been demonstrated that masticatory function among persons with a natural dentition cannot be foretold from the usual clinical examination[1,2] and that among persons with prosthetic appliances an accurate prediction of the chewing ability is not possible at present.[3, 4] Most of the investigators dealing with techniques for construction of prosthetic appliances have based their arguments on concepts derived from clinical examinations. The appliances were not actually tested for their capacity during function. The patient's estimation of the value of an appliance is important, but it is subjective, qualitative, and often influenced by professional opinion. Sometimes it is inaccurate; for example, we have observed several patients who volunteered the information that they had no difficulty in chewing food. Subsequent tests showed that their chewing ability was far below normal and that they were well accustomed to swallowing coarse masses of food. They stated that they could chew any food, but really meant that they could swallow any food.

Two investigators have obtained objective information concerning the aid to chewing efficiency which is provided by removable appliances. Gelman[5] reported four tests on the chewing ability of patients before and shortly after the insertion of partial dentures. The mastication of almonds improved from 6 to 57 units within a few days, and the chewing ability reached a maximum in one to over twenty-four days. His opinion was that the most improvement took place during the first seven to ten days, and afterward there was a slow increase for a longer period of time. Apparently, the only other study was by Claussen, as reported by Schutz.[6] Claussen prepared a partial denture from which individual teeth could be removed. The two premolars each contributed about one-half as much to the chewing ability as did the first or second molar, and the total effect of the denture was to raise the chewing ability by 19 units. These studies demon-

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strated objectively that improvement of chewing ability usually takes place, but certain questions remained unanswered. How much improvement can be expected on the average from each type of appliance, and does the degree of improvement differ greatly among various patients? How much time is required for the patient to achieve adjustment to the restoration and reach his peak efficiency? How do commonly accepted procedures compare with one another in restoring defective function toward normal?

The purpose of this investigation was to evaluate the functional benefit derived from replacement of a single molar tooth and to compare the merits of removable and fixed type appliances. For practical reasons, the study was confined to observations which could be made within a two-week period, and thus the comparisons between fixed and removable appliances did not take into consideration how long the denture maintained its usefulness.

PROCEDURE

Twenty subjects were selected who presented dental deficiencies adaptable to operative procedures in one quadrant of the mouth and who presented no obvious malocclusions, peridontal disturbances, or grossly inclined abutment teeth. Prior to initiation of restorative procedures, the occlusion of each patient was carefully equilibrated. First removable and then fixed prostheses were constructed to restore these deficiencies in each of the subjects.

Study casts were made prior to any operative work. In the construction of removable prostheses, the abutment teeth were prepared for occlusal rests, and the impressions were taken using alginate impression materials. The master casts were keyed and mounted in functional relationship, a slight modification of the technique advocated by Spiro[7] being used. A survey line was outlined on all abutment teeth. In all twenty subjects type 1 clasps were used on the anterior abutments and in eighteen on the posterior teeth. There were two cases in which ring clasps were used on the posterior abutment teeth. The design of the restoration was drawn on the master cast in indelible pencil. The saddle area was relieved with 32-gauge wax, duplicated with hydrocolloid impression material, and dipped in a rosin preparation to facilitate the adherence of the wax and to prevent distortion. The restorations were waxed up in hard casting wax, trimmed to a size consistent with casting, sprued, painted to reduce surface tension, and invested. All restorations were cast with a hard gold "C" alloy and polished.

Each restoration was then returned to the master cast where occlusion was ground to meet centric and functional requirements. A final polish was then put on the restoration. It was sterilized and the tube tooth cemented in place. The restoration was then inserted into the patient's mouth, and spot-grinding was accomplished where necessary (see Fig. 1).

In the construction of the fixed bridgework, all of the teeth were prepared to receive three-quarter crown or full crown restorations. The hydrocolloid impression technique was used to obtain impressions of the abutments, and alginate impressions were taken of the opposing arch. These impressions were rinsed,

boxed, and poured immediately in S. S. White yellow stone. Functional and centric occlusal registrations were obtained with the use of the method described by Spiro.[7] The bridge casts were then placed in liquid petroleum jelly at 100° F. Stephan crown and bridge articulators were then used in mounting the casts and occlusal registrations. The casts were sectioned, and the crowns were carefully waxed up with hard inlay wax. Trupontics were used in maxillary cases, and sanitary pontics were employed in mandibular cases. Care was taken during

Fig. 1.—A typical removable restoration used in this study.

Fig. 2.—A typical fixed restoration used in this study.

the wax-up to obtain proper centric and functional relationships with the opposing teeth. The bridges were then sprued, removed from the casts, painted to reduce surface tension, and invested with Crystobalite investment material. The majority of castings were made with B-2 gold. The bridges were then polished, returned to the casts, and remounted in the articulator. The occlusion was carefully checked and spot-ground intraorally to correct any discrepancies in articulation. A final polish was then applied (see Fig. 2).

Eighteen subjects received first molar replacements, and two obtained second bicuspid plus first molar appliances. Masticatory performance tests were conducted according to the methods of Yurkstas and Manly.[8] These tests are based essentially on the amount of test food passing through a ten-mesh screen at a given point during mastication. Masticatory function tests with peanuts and carrots were performed on each subject prior to any operative work, on the first day of insertion, one week after insertion, and two weeks after insertion of the prosthetic appliance. Control tests were made simultaneously on the opposite side of the dentition and on the experimental side when the replacement could be removed. Altogether 1,600 function tests were required for this study.

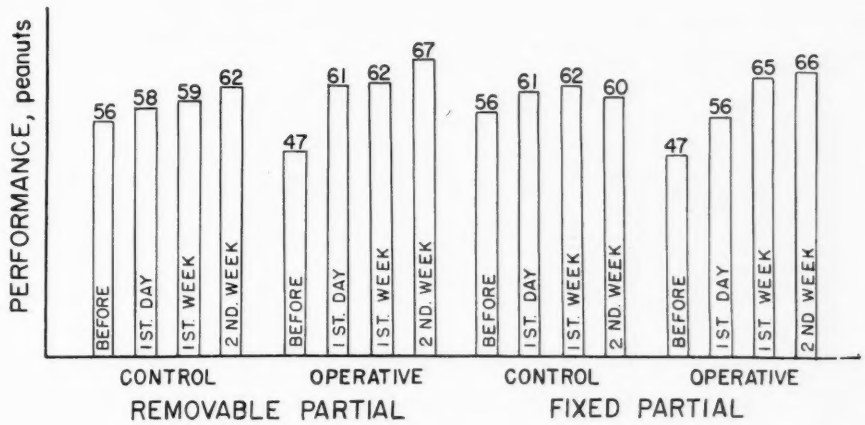

Fig. 3.—Masticatory performance tests.

RESULTS

Fig. 3 demonstrates the results of masticatory performance tests with peanuts over a two-week testing period with both types of prostheses. The bar graphs to the left indicate the mean results obtained with removable prostheses. On the control side a slight increase in masticatory performance was observed. These increases were shown by the "t" test to have no statistical significance.[13] On the operative side there was a definite increase between the before-insertion values and the second week values. This increase was significant to the 1 per cent level. The slight improvement between the first day, the first week, and the second week indicated that a degree of learning may be associated with adjustment to the removable prostheses.

Results with fixed appliances are shown to the right of Fig. 3. Again the control tests showed no differences that were statistically significant. On the operative side the differences in performance before operative procedures and two weeks after insertion were significant to the 1 per cent level. There was no significant increase between the first day and the second week with fixed appliances in place, but the trend indicates that there is learning with the fixed prostheses.

Comparable results were obtained when carrots were utilized as a test food. In this instance the removable appliances seemed slightly more efficient. This may be due to the narrow buccolingual diameter of the supply tooth which was used in the construction of fixed prostheses.

The results of the masticatory performance tests indicate that the replacement of a first molar tooth, either fixed or removable appliances being utilized, increases the masticatory efficiency of the dental apparatus. The magnitude of increase has been approximated by conversion of the "before and after" performances to efficiency according to a recent method introduced by Manly.[9] The increase amounts to about 26 per cent or one-quarter of the capacity possessed by a normal dentition. Perhaps, by coincidence, this is in agreement with the findings of Ono,[10] who concluded that "loss of the first molar caused a damage to the digestive capacity of the teeth of more than one third."

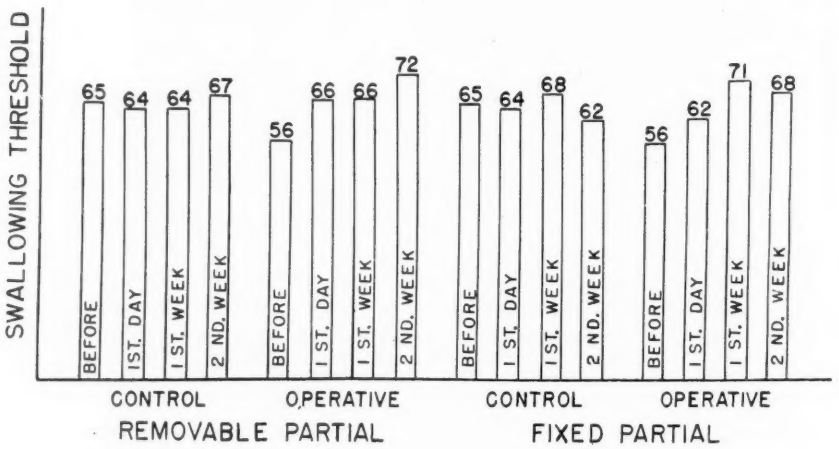

Fig. 4.—Degree of fineness of masticated food at the "swallowing threshold."

Fig. 4 represents the degree of fineness of masticated food at the point where the patient was ready to swallow. This has been termed the "swallowing threshhold."[11] There was no significant difference in swallowing threshold on the control side throughout the test period. This indicated that the tests were reproducible and that familiarity with the testing procedure did not significantly alter the results. In considering the removable restorations, a 16 unit increase in swallowing threshold was found at the end of the two weeks. This increase was significant to the 5 per cent level. Similar results were obtained with the fixed appliances in place. These results indicate that the placement of fixed and removable prostheses causes patients to grind their food finer before swallowing.

Fig. 5 demonstrates that the fineness of particles of food at the swallowing threshold is directly related to masticatory performance. The correlation coefficient between the two variables was +0.7, which was significant to the 1 per cent level. This indicates that the individual with a diminished ability to chew compensates for the dental handicap by swallowing larger particles of food. Persons with

superior chewing ability achieve a finer degree of pulverization at the time of swallowing than do those with an average or poor dentition.

It was still possible that masticatory deficiency was compensated to some extent by an increase in the number of strokes used during mastication. This question was approached by comparing masticatory performance with the number

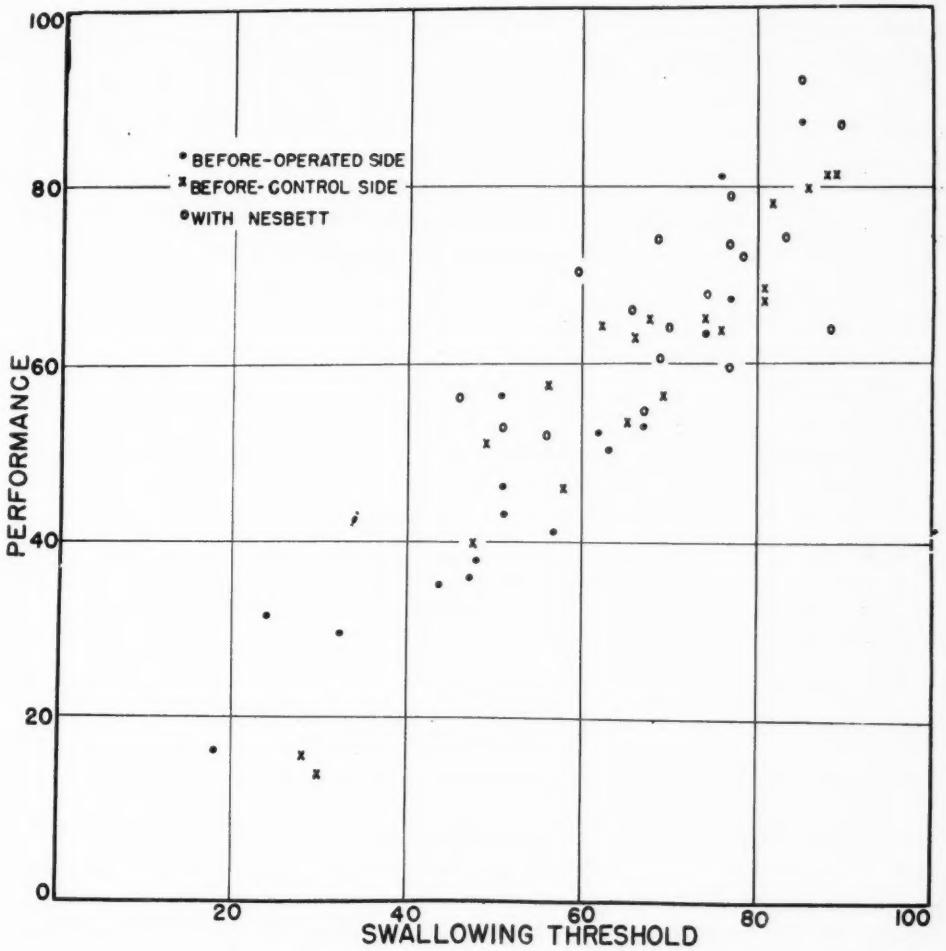

Fig. 5.—Relation of the swallowing threshold to masticatory performance.

of strokes required to prepare the food for swallowing. The lack of any correlation between these two factors indicates that persons who possess an inadequate dentition do not compensate for their masticatory handicap by chewing for a longer period of time. This is in agreement with Dahlberg's findings.[12] It seems apparent that masticatory habits do not change appreciably even though the efficiency of mastication becomes impaired. The patient compensates for loss of masticatory ability chiefly by swallowing larger particles of food.

It was also demonstrated that the number of strokes and the time required to reach the swallowing threshold are reduced when missing teeth are replaced

by fixed and removable applicances. In other words, the subjects wearing prosthetic appliances masticated their food finer, with fewer strokes, and in a shorter time than they did immediately previous to the insertion of the appliances.

Fig. 6 represents the percentage increase in swallowing threshold after the insertion of removable appliances. The fixed appliances followed essentially the same pattern. The before-insertion swallowing thresholds for individuals are plotted along the horizontal axis. The degree of change is shown along the vertical axis. The results indicate that the greatest improvement was shown by patients who possessed a large degree of masticatory impairment. This is demonstrated by the values on the left side of the chart. Persons with a slight impairment, as demonstrated by the values in the right section, improved to a lesser degree.

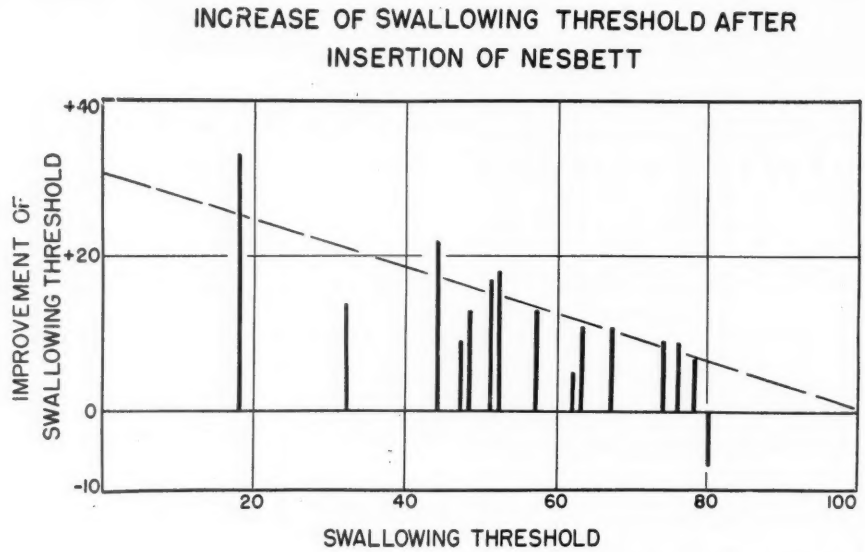

Fig. 6.—Percentage increase in the swallowing threshold with removable prosthesis.

According to this chart, a person possessing a swallowing threshhold value of 50 prior to any operative work will unconsciously increase the swallowing threshold to approximately 80. This represents an over-all increase of 30 units. A statistical analysis of this data showed the Pearson R correlation coefficient to be +0.79. This emphasizes the direct proportion between masticatory performance and swallowing threshold and suggests that, if masticatory performance is improved, swallowing thresholds will be correspondingly increased.

An evaluation of the tests as a whole seemed to indicate that there was no marked difference between fixed and removable prostheses from a functional standpoint. Actually, removable appliances resulted in higher masticatory performance more often than the fixed appliances, but this difference was not statistically significant. The time and the number of strokes required to reach the swallowing point were similar with fixed and removable appliances. It can be concluded that removable prostheses are an efficient functional replacement and that they compare favorably with fixed appliances.

SUMMARY

Removable and fixed prosthetic appliances were constructed for each of twenty subjects in order to replace a missing first molar. (In two cases the second bicuspid was also restored.) Masticatory performance tests with soft and tough foods were made before, immediately after, and one and two weeks following the insertion of the appliance. The degree of pulverization before swallowing and the time and chewing strokes required per mouthful were obtained for each subject at each period.

The insertion of either fixed or removable appliances caused a statistically significant increase in masticatory performance with both hard and soft foods. The two appliances were about equivalent in their effect. Masticatory performance was generally higher after appliances were in place for a two-week period, indicating that individuals learned to use both fixed and removable appliances more efficiently within this time. The duration of this learning period has not been determined.

Subjects with a diminished masticatory capacity swallowed larger particles of food than did those with a normal or superior masticatory performance. Upon the insertion of fixed and removable appliances, most individuals immediately used fewer strokes to pulverize their food finer at the swallowing point. After two weeks of usage, the patients required seven fewer masticatory strokes and six seconds less time per mouthful and at the same time achieved 16 units greater pulverization than they did previous to the insertion of the partial appliances.

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FACTORS INFLUENCING DENTURE FUNCTION

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IN A recent study by the authors, 100 denture wearers were surveyed in order to learn how well the average denture wearer can chew food and how much variation there is among the masticatory functions of different individuals.[1] Some individuals were found to be quite successful in making adequate adjustment to the use of dentures, while others possessed only one-twentieth of the normal efficiency. Very few clues to the reason for such variation were found.

The purpose of the present investigation was to search for factors affecting masticatory performance of denture wearers, a more intensive approach being used. The studies were confined to twenty carefully selected patients, who were chosen because of their willingness and ability to cooperate in a long series of tests and their freedom from abnormalities of the load-bearing gingival mucosae.

In previous studies[1,2,3] from this laboratory, the tests of masticatory function were based on an arbitrary number of chewing strokes, with the result that deficient mastication was disclosed as a larger particle size for the masticated food. It seemed worth while to determine also what effect a defective masticatory ability might have upon the "swallowing threshold," the particle size at which food was considered by the patient to be ready for swallowing.[4] Also, the number of strokes required to reduce the food to this size could serve as a direct index of improvements in denture function, for the numbers would be a direct index of masticatory efficiency. Chewing ability was evaluated both on soft and tough foods, and an investigation was made of the particle size of the food when the subject considered it to be ready for swallowing. The influence of denture stabilization and types of chewing motion were studied, and a comparison was made between chewing on one side of the mouth and chewing without any instructions.

EXPERIMENTAL PROCEDURE

In the previous study the patients were selected at random, and those with abnormal mouth conditions or with ill-fitting dentures were included. One hundred fifty-eight patients were carefully screened to obtain the twenty actually used for this study. Those chosen could be classed as normal rather than superior from the standpoint of denture construction. All were free from clinical signs of irritation of the mucosa or from observable lesions on the gingival mucosa, tongue, and pharynx. Alveolar ridges were normal or superior for patients of their ages. All patients wore full dentures which had adequate retention, tissue coverage, balance, proper vertical dimension, and freedom from muscular interference.

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Most of the patients who were eliminated were unwilling or unable to spend the eight hours needed for the tests. The next largest number could not be used because of mouth soreness due to poor denture fit. Others were omitted because of inadequate dentures, and some persons were not asked to participate because of senility or apparent inability to follow instructions.

Clinical observations included the age of the patient, the type of denture tooth and denture base material, the firmness of the gingival mucosa, and the development of the alveolar ridges. The duration of denture usage and the age of the present denture were recorded. Notes were taken concerning the apparent ease of mastication, the quantity of saliva, and the extent of muscular development. When the head of the condyle could be seen, its movement during mastication was measured with a millimeter scale. Lateral excursion during mastication was likewise estimated during chewing with the millimeter scale placed against the upper central incisors.

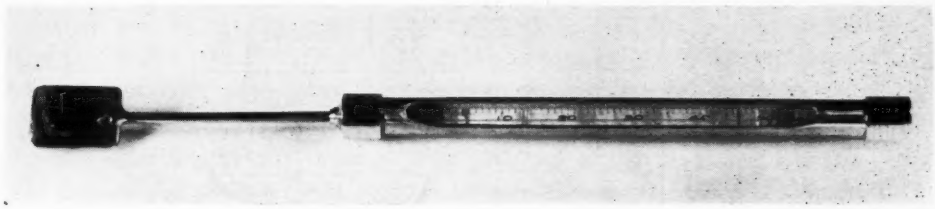

Fig. 1.—An instrument for measuring maximum biting forces of denture wearers.

Food platform area was determined with a special wax for right and left sides of the dentition[5]; this area represents the effective occlusal contact area on one side of the dentition. Measurement of the maximum biting force was obtained in the anterior region of the denture and in the right and left molar regions; some of the observations were made with an electronic force meter,[6] but most were made with a new design of force meter, shown in Fig. 1. This latter instrument consists of a lozenge-shaped stainless steel bulb which is connected by a thin tube to a graduated glass tube. Mercury fills the space within the gnathodynamometer up to the lowest graduation on the glass tube. Force flattens the bulb slightly, expressing mercury from the bulb and permitting the force to be read from the position of the mercury in the tube. Tests on one subject daily for five days showed a duplicability on the average of about one pound.

A variety of tests was conducted on the same twenty subjects for several reasons. In previous tests the subject had been told the number of chews and the weight of the sample he was to use. One purpose then was to study the effect of removing this restriction, thus permitting the patient to select at will the size of portion and number of masticatory strokes, as he would do when eating a meal. In one instance the patient was permitted to chew the food until he considered it ready for swallowing, and the number of masticatory strokes was counted. In a second test he was instructed to chew until told to stop, and he was halted at the number of strokes he had employed in the first test. This

TABLE I. MASTICATION TESTS ON TWENTY DENTURE PATIENTS

	PATIENT NUMBER																				PEANUTS (AVERAGE)	CARROTS (AVERAGE)	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		5 MESH	10 MESH
Preferred side of dentition 3 3-gram portions, 20 chews on each																							
No lateral motion	44	42	29	61	32	18	8	35	29	14	22	28	28	18	29	18	38	39	25	32	29.5	17.5	5.7
Usual motion	46	48	30	43	48	24	13	44	32	15	25	32	30	20	32	23	48	42	31	36	33.1	25.7	7.2
Exaggerated lateral motion	52	46	41	57	48	29	14	45	35	16	26	35	31	22	33	25	52	44	40	40	36.6	27.2	8.9
No restriction on side of dentition, 3 3-gram portions, 20 chews on each																							
Unstabilized	47	49	37	62	37	24	13	43	30	15	24	32	30	19	30	20	40	41	29	35	32.9	22.8	7.2
Stabilized	53	65	32	68	50	20	13	43	40	15	25	32	30	20	30	34	43	41	42	42	40.6	27.6	9.0
Sample selected by patient chewed until ready for swallowing																							
Unstabilized first test (average of triplicate)	65	66	52	68	63	50	28	64	50	24	30	37	35	25	39	29	60	52	74	64	48.8	44.2	15.8
Strokes used per portion	39	45	66	63	56	48	67	42	50	35	40	26	35	43	34	56	34	73	89	64	50.3	49.1	49.1
Second test	70	64	50	70	54	44	26	66	52	25	31	37	35	24	37	30	61	50	75	65	48.3	41.3	15.1
Stabilized (average of triplicate)	67	67	46	77	64	31	21	70	61	27	32	44	38	30	45	78	69	61	81	69	38.5	45.7	18.8
Strokes used per portion	38	33	52	50	50	40	50	35	44	26	29	20	29	36	25	42	24	42	72	52	39.5	39.0	39.0

comparison served to demonstrate the duplicability of the mastication process. Another group of three tests served to disclose the influence of lateral motion during mastication. Another group of studies evaluated the influence of denture stabilization on masticatory performance. Eight different tests in all were required of the subject, both with peanuts and with carrots (total of sixteen).

During the first three tests the patient was restricted to the side of the dentition he preferred to use. Three-gram portions of Planter's peanuts were supplied to the patient, and he was instructed to chew each for twenty masticatory strokes. The chewed food was expectorated with mouth rinsings into a beaker and stirred and washed with water through a ten-mesh screen in agreement with the method of Yurkstas and Manly.[5] The portions passing through and remaining on the screen were collected separately in centrifuge tubes and their volume read after centrifuging. The performance figures as given in Table I represent the percentage of total food recovered which passed through the ten-mesh screen. Separate tests were made with no lateral motion (No. 1), with the usual motion (No. 2), and with an exaggerated lateral motion (No. 3). With tests No. 4 and 5, the portions were weighed and the masticatory strokes were counted, but there was no restriction as to mastication on one side of the dentition.

Tests No. 6, 7, and 8 were selected in order to represent the whole process of the food selection and mastication. The quantity of sample was left to the patient, and the number of chews was determined at the point at which the patient judged the bolus to be ready for swallowing. Test No. 7 discloses the reliability of test No. 6. Here the patient was required to chew until told to stop and was required to use the same number of strokes he had previously used in test No. 6. Tests No. 5 and 8 were performed after application to both dentures of a commercial denture powder consisting of karaya gum N.F. VIII, adkalinized with sodium borate (U.S.P.), in order to try to increase denture stability. These three tests supplied information beyond that obtained when the number of chews was restricted. The percentage figures indicate the "swallowing threshold," the particle size of food which the patient is willing to swallow.[4] The number of strokes used is an indication of the effort required to prepare the food for swallowing.

RESULTS

The complete data on mastication of peanuts by twenty subjects are given in Table I. The findings with carrots and peanuts are generally similar, and the peanut test is more reproducible since the food is more uniform. Hence, the findings on peanut tests are given in detail, whereas only average values for carrots have been reported, calculated both on the five- and ten-mesh screens. The reliability of the methods is disclosed in Table I by two comparisons. In test No. 2 there is a restriction as to chewing on one side of the dentition. In test No. 4 there is no such restriction. Otherwise, the two tests are the same. Note that the average performance is almost identical for peanuts and ten-mesh carrots and similar for five-mesh. Test No. 6 may also be compared with test No.

7. Here the samples were selected by the patient and chewed until ready for swallowing in No. 6 and chewed for the same number of strokes in No. 7. There is surprisingly close agreement between the average percentages, both for carrots and peanuts, indicating that there is good uniformity in the whole process of selecting a sample of food for mastication and in carrying through the masticatory act.

The influence of lateral motion can readily be seen by comparing tests No. 1, 2, and 3. The restriction of lateral movement produces less effective mastication, and an exaggerated lateral movement increases the amount of pulverization of food. Permission of lateral movements increased performance in eighteen out of twenty cases for the peanut and five-mesh carrot tests and in every case for the ten-mesh carrot tests. The performance for peanuts rose from 29.5 to 33.6 on allowing lateral movement, and from 33.1 to 36.6 on beginning exaggerated movement. This would correspond to an efficiency increase of approximately 20 per cent.

These findings suggest that the extent of lateral motion might be a factor capable of accounting for part of the difference between poorly functioning and well-functioning dentures. The clinical observations, however, indicate that this factor does not actually operate, since nearly all of the lateral movements ranged from 5 to 7 mm. The actual lateral movements employed by different persons were nearly always the same and thus cannot account for much of the difference in the ability to masticate food.

Influence of Denture Stability.—It was considered that denture adhesive powder might improve the denture stability and thus provide a means of evaluating the effect of denture stability without any modification in the patient or the denture itself. This question was evaluated by comparison of tests No. 4 and 5, with control over the portion size and chewing strokes. An increase in the performance was observed both with peanuts and carrots, but the difference was not significant, probably because of the limited number of tests. The increased performance was better shown by studies made previously on 100 denture patients; their performances increased on the average from 38 to 47 per cent, and this change was found to be statistically significant at the 1 per cent level. The 100 patients included a considerable number of persons with ill-fitting dentures, whose denture stability is known to be improved by denture powder. The present twenty patients had been carefully selected to eliminate ill-fitting dentures, mouth soreness, and abnormality. Apparently, the denture stability is a factor in determining the extent to which a denture can be manipulated efficiently, both with poorly or well-fitting dentures.

In tests No. 6 and 8 where the sample size and the number of chewing strokes were left to the patient, there was likewise better average performance with the stabilized dentures, both with peanuts and carrots. It was surprising, however, to find that fewer strokes were taken by the patients. Apparently, the patient is able to sense immediately that he is achieving greater masticatory efficiency and accordingly spends less effort in preparing the food for swallowing. The differ-

ence between the swallowing thresholds cannot be shown to to be statistically significant, but the difference between strokes is significant at the 5 per cent level.

Relationship Between Masticatory Ability and Particle Size of Food Swallowed.—It has been reported by Dahlberg that patients do not compensate for inadequate dentitions by increasing the time of chewing or the strokes used.[7] One might assume from this that larger particles of food were swallowed by persons with an inadequate dentition. This can be shown directly from the data in Fig. 2. The masticatory performance with peanuts or carrots is plotted on the horizontal scale and the swallowing threshold for the same food on the

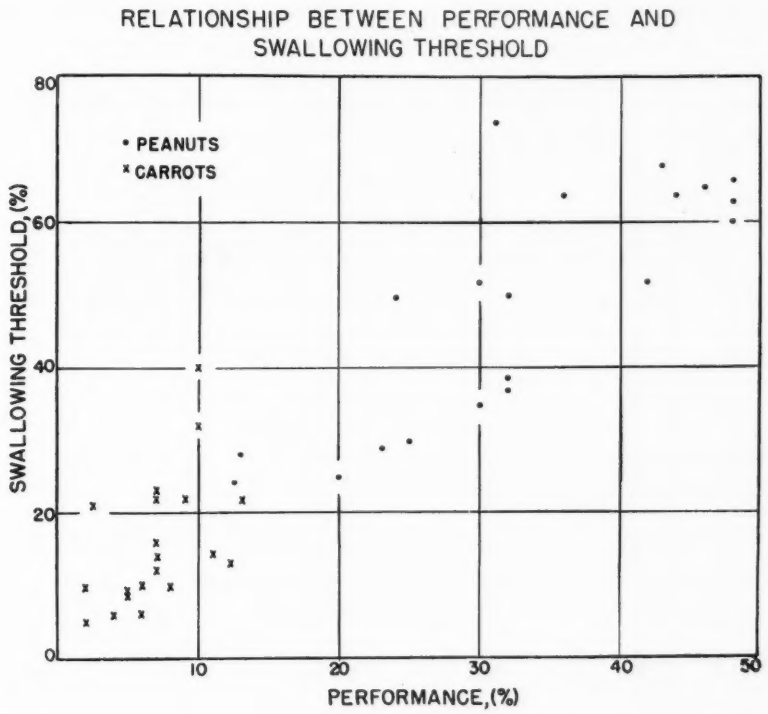

Fig. 2.—The relation between masticatory performance and swallowing threshold with peanuts and carrots as test foods. The particle size at swallowing depends directly upon the amount of pulverization of the food which can be achieved by the patient in twenty masticatory strokes.

vertical scale. There is a good relationship between the particle size of the food that is swallowed and the masticatory performance. This means that persons with poor performance are apt to swallow large particles of food, while those with good masticatory power will pulverize their food more finely. Note also that the same type of relationship holds for both peanuts and carrots, which suggests that the food will be swallowed whether it happens to be coarse or fine after certain masticatory effort has been expended. The number of strokes employed was compared with the masticatory performance of a denture wearer. There was no relation, indicating that the denture wearer does not usually compensate for

TABLE II. CLINICAL OBSERVATIONS ON TWENTY PATIENTS STUDIED

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Age of patient (years)	41	39	71	40	39	65	68	65	65	52	50	41	40	57	38	70	34	83	55	59
Type of tooth	AN	AN	H	AA	PA	PA	PA	AN	AN	PA	PA	PA	PA	PA	AN	PN	PN	AN	H	PA
Age of denture (years)	2	2	2	2	6	27	25	4	4	3	5	14	15	20	1/25	4	4	2	½	½
Musculature	G	G	N	N	N	P	P	P	N	N	G	P	P	P	N	P	G	G	G	P
Ridge development	G	G	G	G	G	N	N	N	P	N	N	N	N	N	N	N	G	N	G	G
Lateral movement (mm.)	6	2	6	2	7	4	6	5	6	6	7	8	6	7	6	5	7	6	7	6
Condylar movement (mm.)				11	11			10	10	11	12	10		10	11	11		11	11	9
Tissue compressibility	M	M	M	M	M	L	S		M		L		N				S		M	M
Saliva flow	M	L	M	M	M	L	S	S	S	M	L	S	L	L	M	M	M	S	S	L
Chewing facility	G	P	G	G	G	N	N	G	N	P	P	N	P	P	N	P	G	G	G	G
Tough food tolerance	G	P	G	G	G	P	P	G	P	P	P	N	P	P	P	P	G	G	G	G

PN = porcelain nonanatomic
PA = porcelain anatomic
AN = acrylic nonanatomic
AA = acrylic anatomic
H = I. R. Hardy's tooth form

G = good
N = normal
P = poor
S = small
M = medium
L = large

poor chewing ability by a greater effort in mastication. The number of strokes used seems to be dependent upon some attribute of the patient and not upon the effectiveness of his denture.

Prediction of the Chewing Ability of the Patient From Clinical Examination.—In Table II is given a brief tabulation of data concerning each patient, the denture, and the clinical findings concerning the mouth. Certain of these findings are related suggestively to the ability to chew food, and this information is presented in histogram form in Fig. 3. The lateral movement of the condyle (when it could be observed), the tissue displaceability, and the saliva flow gave no indication of being important for increasing the patients' chances of superior masticatory ability. The ridge development, the musculature, the chewing facility, and

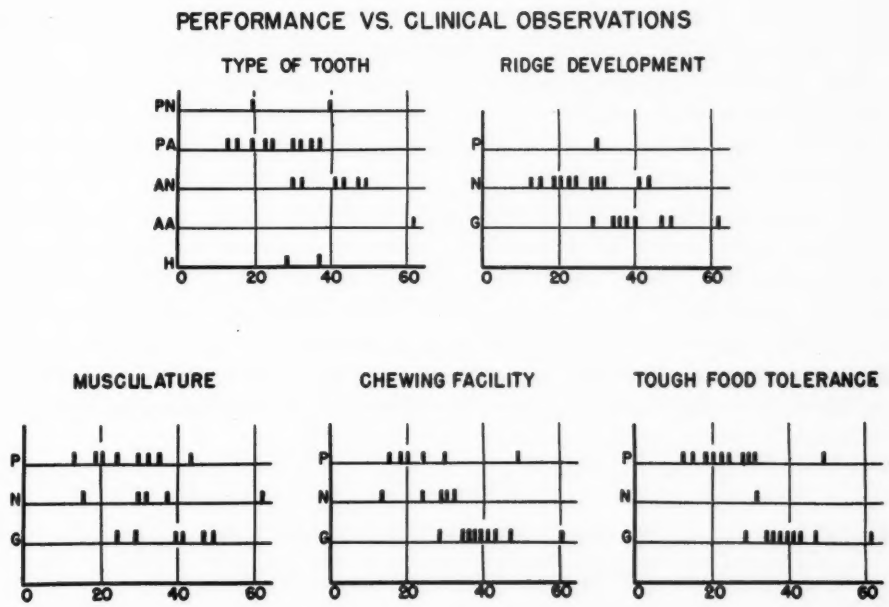

Fig. 3.—The relation between masticatory performance of denture wearers and type of tooth, ridge development, musculature, chewing facility, and tough food tolerance. List of abbreviations: P = poor; PN = porcelain nonanatomic; PA = porcelain anatomic; AN = acrylic nonanatomic; AA = acrylic anatomic; H = I. R. Hardy's design; N = normal; G = good.

tough food tolerance appear to be factors which should be considered in later studies. Also there is slight indication that performance with a nonanatomic tooth is greater than that with the anatomic tooth. Yet three of these factors probably are the result rather than the cause of good chewing ability. The patient with good masticatory performance would be likely to have greater chewing facility, more willingness to chew, and ease in mastication than would be the person whose performance was poor. A person with good performance would be more apt to tolerate tough foods than would one with poor performance. These things in turn might lead to better muscular development.

SUMMARY

A large number of masticatory function tests have been carried out on twenty selected denture wearers for the purpose of obtaining clues concerning the factors affecting masticatory function. The function tests include effective occlusal area, maximum force, and sixteen performance tests with two test foods.

It was found that the extent of lateral movement was capable of affecting the masticatory performance of denture wearers. The actual lateral motion used by different patients was nearly always the same; hence, it is unlikely that this factor will account for the wide functional difference among different denture wearers.

Denture stability was shown to be a factor capable of increasing masticatory function of denture wearers, when tests with and without denture adhesive powder were used as the method of comparison. Increasing the stability with denture powder was reflected in the fewer strokes required for reaching the swallowing stage and in similar or better pulverization of the food.

Poor masticatory performance among denture wearers was found to cause the individual to swallow coarser food particles; there was no evidence of a general tendency to compensate for the inadequate dentition by chewing the food for a longer period of time.

The clinical findings did not prove to be useful as guides for predicting the masticatory performance of a particular denture wearer. Lateral movement, condylar movement, tissue compressibility, and saliva flow did not seem to be related to performance and mastication. There was some indication that the type of tooth, degree of ridge development and muscular development, chewing facility, and tough food tolerance were related, but it is probable that the last three factors are effects and not causes of differences in masticatory function.

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THE SELECTION AND ARRANGEMENT OF THE ANTERIOR TEETH IN PROSTHETIC DENTURES

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THE selection and arrangement of the anterior teeth for our denture patients present esthetic and functional problems which cannot be decided by any system of arbitrary measurements taken either inside or outside of the mouth. In dental college, back in 1901, we were taught the temperamental theory of tooth selection. Each patient was classified as either nervous, sanguine, bilious, or lymphatic, and teeth were chosen which the manufacturer had designed for that class. In practice we had great difficulty trying to decide into which category each patient should go, and when we did decide, each manufacturer had a different form of tooth for that class. While this system was unworkable and left us very much on our own, we still have the greatest admiration for those old-time professors who made such interesting lectures out of the only material they had available.

A few years later the geometric theory of tooth selection was presented to the profession. Dr. J. Leon Williams was reputed to have discovered that there was a definite relation between the outline form of the face and the outline form of the upper central incisors. Faces were classified as square, tapering, and ovoid, and the manufacturer gave us teeth of the same classification, with numerous blends to conform to facial blends. This system was simple and comparatively easy to apply. It was widely accepted by the profession, taught in many schools, and incorporated in prosthetic textbooks. A troublesome esthetic problem was blueprinted for us, and everyone was happy.

Then, around 1920, Nelson[1] did some very interesting work on arch form and alignment form. From his study of natural dentitions, he concluded that there was a definite relation between the form of the maxillary arch and the alignment form of the upper anterior teeth and stated that we could get a cue from the arch form as to what the alignment of the natural teeth had been.

Nelson classified arch forms and alignment forms as square, tapering, and ovoid and gave the characteristics of each. In the square arch the vault tends to be broad and shallow and the ridge line to be square or rectangular. In the tapering arch the vault is high and inverted V-shaped, and the ridge line tapers toward the front. In the ovoid arch the vault is medium high and rounded, and the ridge line is somewhat ovoid. In the square alignment the teeth are set straight up and down, the incisal edges are even, and all are set to the segment of a big circle approaching a straight line. In the tapering alignment the teeth slant out, the incisal edges are forward from the cervical, the central incisors

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tend to overlap, lateral incisors are shorter than the central incisors, and all are set to a V-shaped alignment. In the ovoid alignment the central incisors slant slightly inward, and there is a characteristic spacing between them; the lateral incisors overlap the central incisors and are depressed at the neck, leaving the mesial shoulder of the cuspids prominent; all are set to the segment of a small circle.

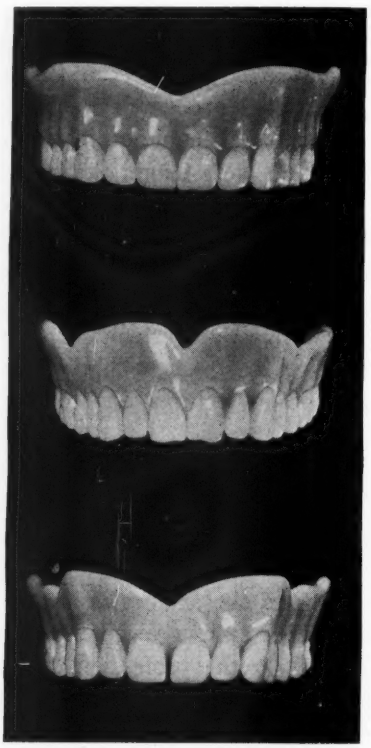

Fig. 1.—Three setups, namely, square, tapering, and ovoid, of the same five-phase mold M42C.

Nelson contended that the alignment form was a much more important factor than the outline form of the teeth, and when I saw the evidence, I heartily subscribed to his view. We set up three sets of teeth of the same mold and hue, one to each alignment form. To the eye, they looked like three entirely different sets of teeth (Fig. 1). We had selected a blended mold that was neither dominantly square, tapering, nor ovoid, yet in the square alignment the teeth looked square, in the tapering alignment they appeared tapering, and in the ovoid alignment they looked ovoid.

It was quite clear that, as we rotated a tooth or changed its inclination from the vertical, it presented a different outline form to the eye. It was also quite obvious that we could select teeth by the face form theory and by the alignment make them appear that they did not belong to the patient. On the other hand, we could select teeth that did not conform with the face form and by the alignment make them appear, when placed in the mouth, like they had grown there.

These observations coupled with the fact that I had seen tapering teeth in square and ovoid faces, square teeth in tapering faces, and ovoid teeth in square and tapering faces exploded the face form-tooth form theory in my estimation. Down through the years I have found Nelson's ideas of alignment form most helpful in getting pleasing esthetic results for edentulous patients. These alignments are very flexible and lend themselves to unlimited modification. In cases where the maxillary ridge has been radically changed by tissue atrophy, we can often get a cue from the central portion of the vault as to whether it was originally broad and shallow, high and inverted V-shaped, or medium high and rounded.

In 1936, Stein[2] of the Department of Anthropology, Columbia University, challenged the geometric theory of tooth selection on the grounds that it had no scientific basis. He said that Williams was the first one to demonstrate conclusively that there was no harmony between face form and tooth form and cited the epochal paper published in 1914 in the *Journal of the Allied Dental Societies* where Williams[3] recorded the results of an extensive investigation on this subject, in which he demonstrated wide teeth in narrow skulls, narrow teeth in wide skulls, long teeth in short skulls, short teeth in long skulls, dissimilar teeth in similar skulls, and similar teeth in dissimilar skulls. With a brilliant array of carefully prepared evidence he proved beyond question that in nature harmony of tooth form and face form is the rare exception and not the rule.

He gave the following quotations from William's paper as of historical importance.

> "While the view of a considerable number of skulls is before you, I will once more ask you to note the fact mentioned several times, during the course of this lecture, that Nature does not always produce a definite type of tooth for any given form of skull . . . .
>
> "Again I say, the proof that Nature produces no perfect harmonies of relationship in the different parts of organisms is to be seen on every hand. It is before our eyes all the time . . . . More than that, I will say that anyone who will take the trouble to examine and compare forty or fifty skulls from almost any race will be forced to the conclusion that if he wishes to follow Nature blindly in the matter of adapting teeth to facial contour he has a fairly wide range of choice in making his selection.
>
> "Is there anything more evident to us as we walk up and down the streets or stand in any place where fellow mortals congregate than the incongruities of Nature? Even the most fortunate would probably not be willing to give an absolutely unqualified receipt in full to Nature on taking a critical survey of himself in his mirror. Why, then, should we assume that Nature always produces teeth in perfect harmony with face and features? Why should they be an exception to the almost universal rule to the contrary in other particulars?
>
> "I have never heard anyone assert that all other features of every human face were in perfect harmony."

Stein, in his treatise on this subject, gave us further proof and then presented in masterful manner the anatomic characteristics of the anterior teeth which most influence esthetics in prosthetic dentures.

> "Upper anterior teeth are like fingerprints; there are no two alike. They vary from one individual to another. This variability manifests itself in size, color, form, contours, and surface markings.

"Throughout the races of mankind, incisors are different—yet they all have basic patterns by which they may be identified as human. These basic patterns, or the ways in which teeth resemble each other, are the anatomical constants. The ways in which teeth differ from one another are the anatomical variants.

"The anatomical constants give the tooth its general form whereas the anatomical variants give the tooth its individuality or personality.

"In prosthetics the outline form is relatively unimportant for it is not a constant feature throughout life. The forces of abrasion and attrition are continuously wearing down the incisal and proximal margins. The tapered sides of an incisor in a young person may be worn to parallel sides by proximal abrasion (Fig. 2).

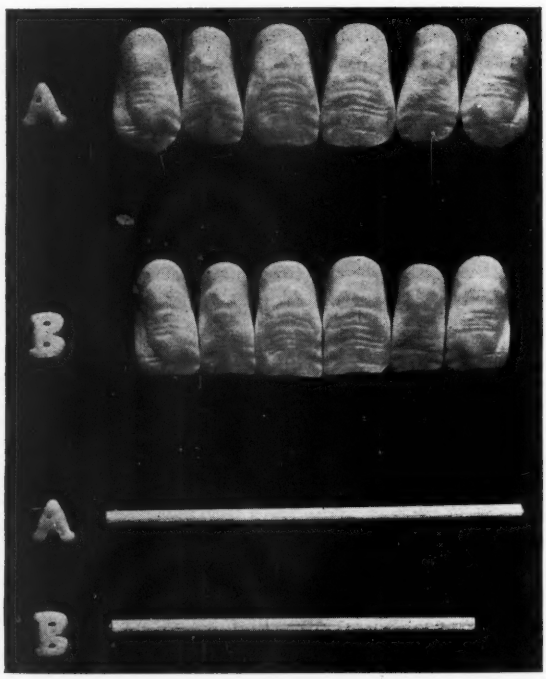

Fig. 2.—Proximal abrasion.

"Thus the outline of a natural anterior tooth is subjected to change throughout life. In any prosthetic setup, the shape or outline of the teeth can be controlled by the alignment and manipulation of the base material over the neck. The surface contours and markings of the incisors are of major importance in prosthetics. The mesiodistal contour is the most influential determinant of light reflection from the surface of a tooth (Fig. 3). In each case, the delicate surface undulations disperse the light in their own characteristic way. This contour gives the tooth its personality.

"The cervicoincisal contour combined with the mesiodistal produces great complexities in the surface topography of these teeth—any kind of cervicoincisal curvature is apt to be associated with any mesiodistal curvature.

"Then there are many variations of surface markings. Some are inherited—others are acquired during developmental periods because of metabolic irregularities. There may be grooves, ridges and lines—horizontal and vertical—small flat areas—concave pits—diagonal channels (Fig. 4).

"These important anatomical variants are all ignored by the classification of teeth into geometric figures—squares, triangles, and circles.

"Central incisors are different in all individuals. Like faces and fingerprints, they are inherited from parent to offspring. They obey the same laws of heredity as any other part of the body. There are dominant family traits in teeth just as in faces. The selection of teeth for an edentulous patient is a problem in biology, and not in geometry. A patient's blood relative is a better clue to the form of his missing teeth than the outline form of his face. The dentist's most scientific approach is the realization that no one has yet written a foolproof formula for the solution of this biological problem."

Stein gave practical expression to his concept of labial surface contours in his carvings of the five-phase anterior teeth.

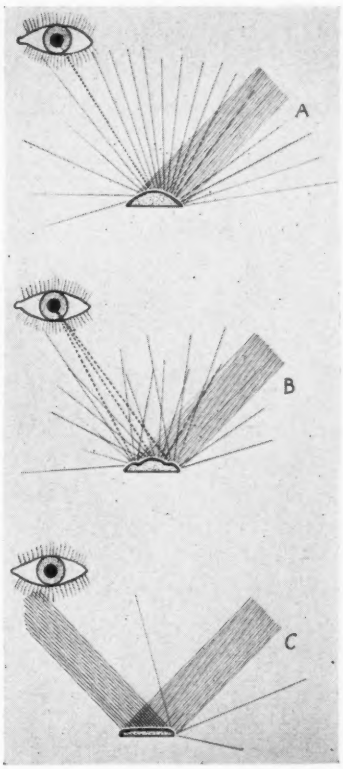

Fig. 3.—Light reflection from the surfaces of teeth.

From the standpoint of esthetics our denture patients fall into two main groups: (1) those of whom we have pre-extraction records and (2) those of whom we have no pre-extraction records. In both cases it is well to postpone the selection of teeth until the casts are mounted in the instrument in centric jaw relation to an accepted vertical closure. Then we can see the distance or working space between the edge of the occlusion rim and the cast and are in a better position to gauge the length of tooth required, whether it be long or short or short bite with long ridge lap. Where we have pre-extraction records we have the size, shape, and arrangement of the teeth, and our first decision should be whether we wish to reproduce these or not. The irregularities may be a deformity; the teeth

may be too long or too big for the patient. It is generally recognized that artificial teeth the exact dimensions of the natural ones sometimes look larger in the mouth than the natural teeth did. We can observe the labial surface contours to see whether they are curved or flat; we can see the degree of vertical overlap of the anterior teeth, and here the functional problem enters in.

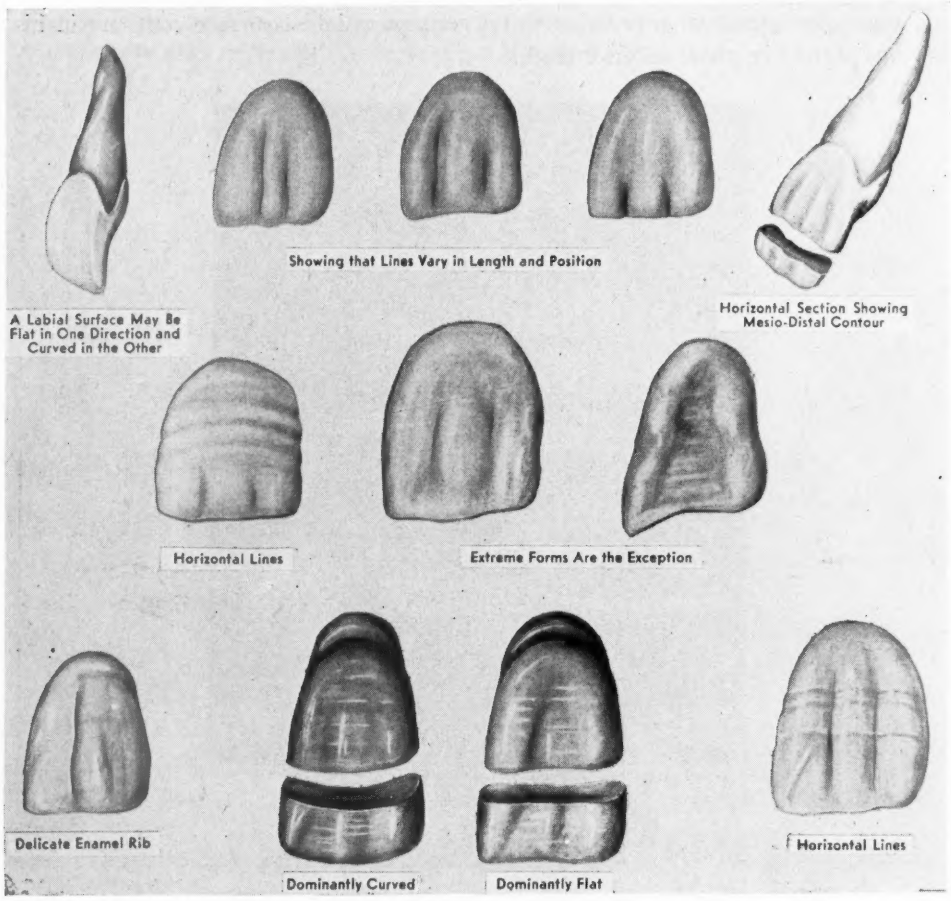
Showing that Lines Vary in Length and Position
A Labial Surface May Be Flat in One Direction and Curved in the Other
Horizontal Section Showing Mesio-Distal Contour
Horizontal Lines
Extreme Forms Are the Exception
Delicate Enamel Rib
Dominantly Curved
Dominantly Flat
Horizontal Lines

Fig. 4.—Variation in the labial surfaces of teeth.

In the natural dentition each tooth is individually supported, while in denture replacements all teeth on the supporting base function as a unit; therefore, steep vertical overbite of the anterior teeth is contraindicated since it restricts forward or lateral movements and tends to unseat the dentures. Vertical overlap should be reduced to a minimum so that these horizontal movements may be made without anterior interference.

Ridge relation is another functional factor. This we can observe on the instrument. The nearer we can set the teeth over the ridge, the more stable the dentures will be. Teeth set forward off the ridge induce leverage and tilting when

vertical pressure is applied. To get the best esthetic result in some cases we have to set the teeth out off the ridge. When esthetic and functional requirements clash in this manner, we should discuss this problem with the patient and make whatever compromises we can in the most favorable direction. When we decide that the teeth are too long or too big and the irregularities are extreme, we can reduce the size and modify the irregularities, yet keep the same general effect and get a more pleasing esthetic result. Only when we have all these facts before us are we in a position to decide what form and size of teeth to select and how to arrange them.

When we have no pre-extraction records, we can ask to see some close blood relations, as Stein suggests; then, we can observe family characteristics, labial contours, alignment forms, and so forth. We may also get some information from the maxillary cast, as Nelson suggests, which may guide us to an acceptable alignment form.

The width of the mouth is another factor to consider. The upper cuspids generally occupy a position just inside the corners of the mouth where the ridge turns backward. Lines drawn on the occlusion rim in this area will give us an approximate over-all width of the six anterior teeth. In those cases it is a matter of arranging the teeth so that, when the patient smiles, the over-all effect will be in harmony with the whole background, and there will be no interference in functional movements. We may have to make several alterations in the alignment before we get the desired result.

When we consider all the variable factors that enter into the picture and influence our composition, we can readily see the fallacy of any system of arbitrary measurements for the selection and arrangement of the anterior teeth in prosthetic dentures.

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THE CONSTRUCTION OF A METAL MOLD FOR ACRYLIC TEETH

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THE use of stock teeth is very often a definite handicap in obtaining a natural-appearing and esthetic denture. Mass-produced teeth have a very regular color distribution, and, although various shades of teeth are available, the color and contour changes which occur in natural teeth with increasing age are not reproduced in these teeth. Teeth of different shades may be used in the same denture to break up the monotony of color distribution, but the natural variations of color as they occur within the individual teeth cannot be imitated.

Following is a description of the procedure for the construction of a permanent metal mold in which acrylic teeth may be molded, colored, and stained as desired for the individual patient.

PREPARATION OF WAX TEETH

Six anterior stock teeth of the general size and shape required, either acrylic or porcelain, are selected. The teeth selected in this case were acrylic (Fig. 1). The stock teeth are sprued with 8-gauge, round wax rods as shown in Fig. 2. If porcelain teeth are used, they are treated in the same manner, except that the pins are covered with wax. The teeth are invested in plaster, leaving the labial one-half and the sprues exposed (Fig. 3). The plaster is carefully trimmed around the teeth so they are not locked in the first one-half of the plaster mold by undercuts. Notches are cut in the plaster, the surface is coated with petroleum jelly, and the second one-half of the mold is poured. The mold is set in warm water for a few minutes and then opened. The wax and teeth are removed, the external openings of the sprues are flared, and the two halves are washed with boiling water to remove all debris and wax. The two halves of the mold are treated with a good wax lubricant and are placed together and held with a small clamp or with rubber bands. Inlay wax is melted into each of the sprue holes. It is important that the wax be very hot when it is flowed into the mold so that it will not freeze before the mold is full. The mold is cooled in cold water and opened (Fig. 4). The wax teeth are removed from the mold, and the sprues and excesses are cut away. The wax teeth are carved and recontoured to suit the individual preference. A good deal of time should be spent at this point in carving the wax teeth to produce a pleasing, esthetic, and natural-appearing tooth. It is generally advantageous to increase the labial convexity of the teeth and accentuate the labial anatomy (Fig. 5).

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CASTING THE MASTER TEETH

The wax teeth are sprued with 10- or 12-gauge wax sprues and are cast in technic metal, brass, or any suitable inexpensive material. Brass was used

Fig. 1.—Stock teeth selected.

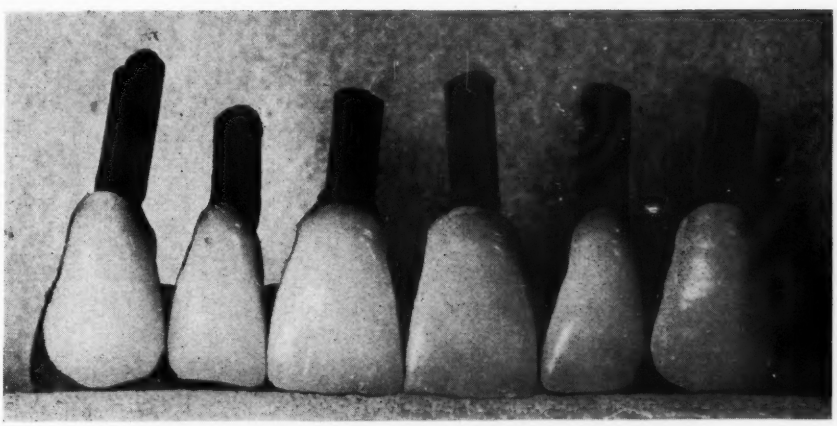

Fig. 2.—Sprues on the stock teeth.

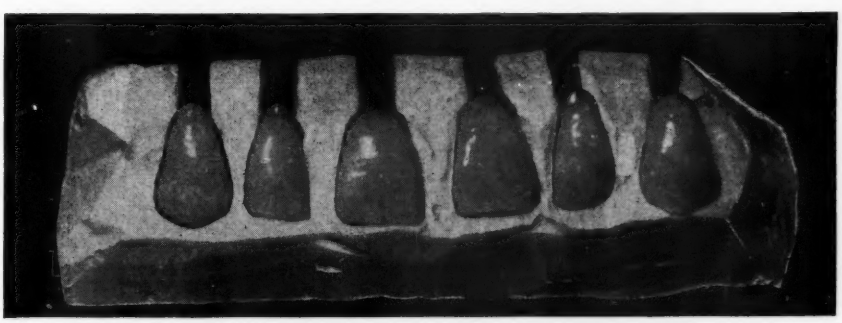

Fig. 3.—Teeth invested in plaster of Paris.

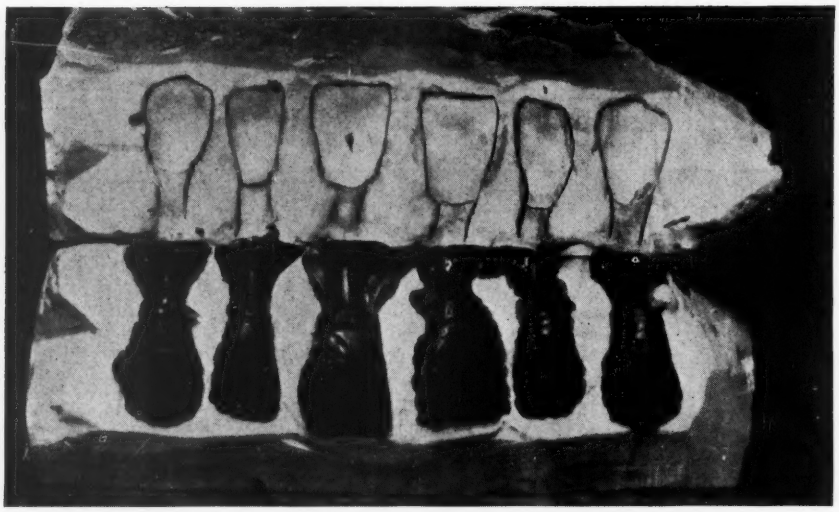

Fig. 4.—Wax teeth in the open plaster mold.

Fig. 5.—Wax teeth modified to individual characteristics.

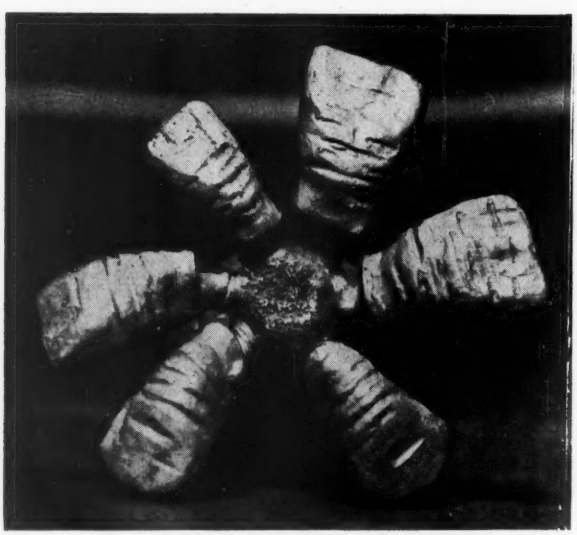

Fig. 6.—The teeth are cast in brass.

in the casting in Fig. 6. The brass teeth are cut off the sprues and polished (Fig. 7). Additional refinements may be carved into the teeth at this time with burs and stones.

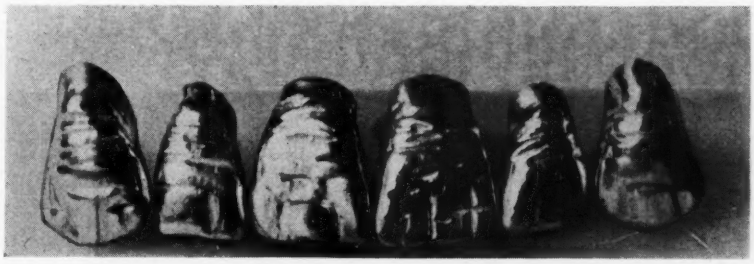

Fig. 7.—The metal teeth are polished.

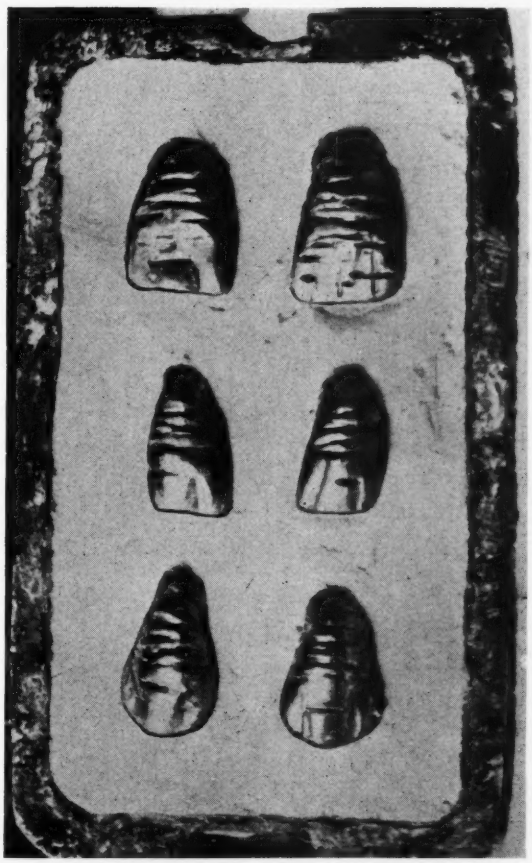

Fig. 8.—The metal teeth are flasked in an acrylic flask.

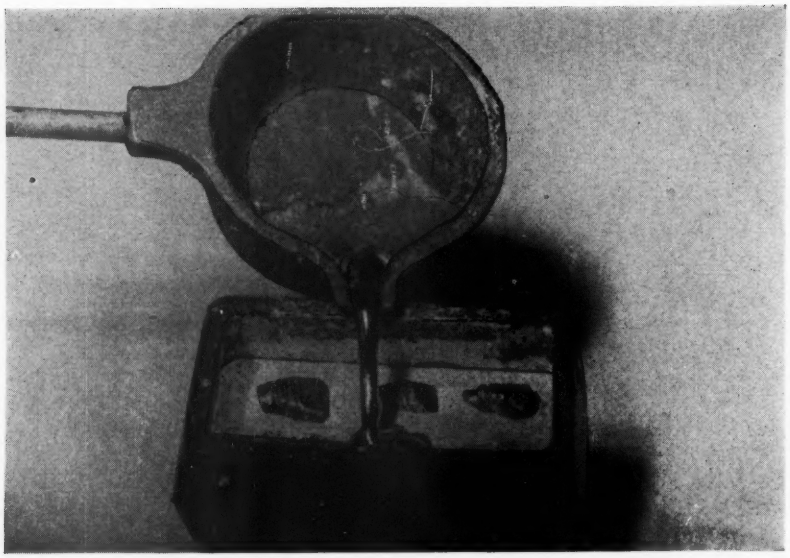

Fig. 9.—The metal mold is poured.

Fig. 10.—The first one-half of the metal mold with the brass teeth in position.

POURING THE METAL MOLD

The polished brass teeth are invested in plaster in a small acrylic flask so that the labial one-half is exposed (Fig. 8). This one-half of the flask with the invested brass teeth is placed over a low flame of a Bunsen burner and is baked slowly for approximately one hour to remove all moisture from the plaster. By holding a mouth mirror over the flask, one can determine when the moisture has been completely eliminated. The complete elimination of moisture is essential.

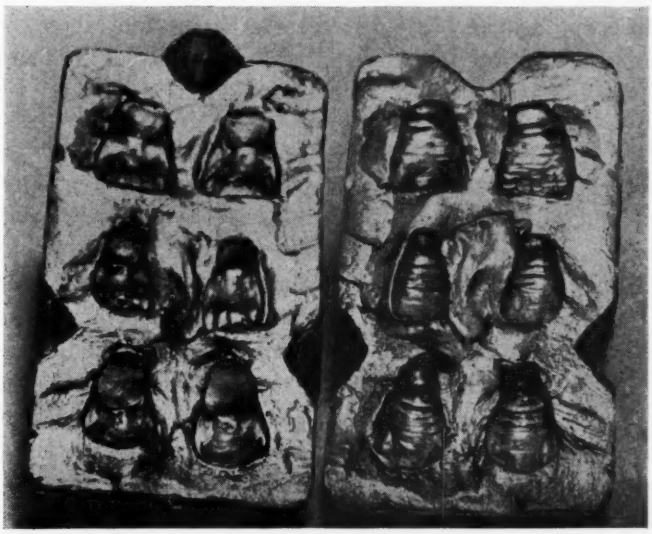

Fig. 11.—The completed metal mold.

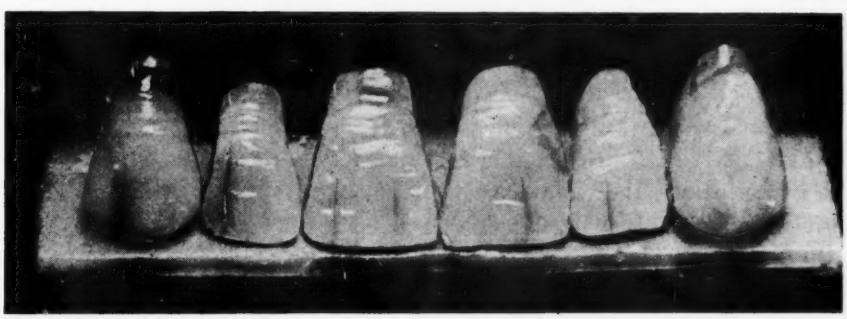

Fig. 12.—The completed acrylic teeth.

The side of the second one-half of the flask is placed in position, and, while the investment is still hot, the first one-half of the permanent mold is poured (Fig. 9). The material used is a low-fusing alloy named CerroTru,* which was suggested to me by Dr. I. R. Hardy. This metal melts at 270° F., and it is very stable in character. It has very little shrinkage on cooling. The metal is poured to a depth of about three-eighths of an inch. When the metal has cooled, the flask is opened, the brass teeth and plaster are removed, and the first one-half

*Made by Cerro De Pasco Copper Corp., New York, N. Y.

of the metal mold is cleaned with soap and water. Two or more deep notches are cut in the edge of the mold to act as keys for the second one-half of the mold. The surface of the mold between the brass teeth is painted with a separating medium. Nail polish has been found to be effective (Fig. 10). The first one-half of the mold is replaced in its one-half of the acrylic flask and warmed slightly. The second one-half of the mold is poured. A successful pour is not always obtained the first time, but an unsuccessful pour can be remelted and repoured. When the mold has cooled, it is removed from the flask, and the two halves are separated by inserting a knife blade between the halves and tapping lightly. The nail polish is removed with ether or any other suitable solvent. The mold is now ready for the processing of acrylic teeth (Fig. 11).

MOLDING THE TEETH

The desired shade of acrylic powder is mixed with monomer in a small mixing jar until the mixture is at a puttylike stage. An excess is placed in each tooth mold, wet Cellophane is placed over the teeth, and the mold is closed with a "C" clamp. Complete closure of the mold is not advised at this time. The clamped mold is placed in boiling water for about thirty seconds and is then removed and opened, and the flash or excess is trimmed with scissors. The acrylic teeth are now in a rubberlike stage and can be handled with little danger of distortion. The incisal portion of the teeth is cut away to allow for the packing of the incisal color. Varying amounts of the incisal portion may be cut away, depending on the amount of the darker incisal color desired. Lateral incisors usually have the greatest amount of incisal color and cuspids the least. The cuts should bevel so that the body and incisal colors will blend without a sharp line of demarcation.

The teeth are replaced in the mold, and the incisal shade is added by the powder and liquid method; i.e., the incisal powder is placed on the teeth, and monomer is added until all the particles of powder have been moistened. The mold is again closed with wet Cellophane, clamped, and placed in boiling water for one minute. The mold is opened once more, the teeth are removed, the flask is trimmed, and the teeth are now ready for staining. The stains come in the form of an acrylic powder which is applied to the tooth in the dry state and is moistened with monomer after application. Deep staining is done by cutting into the teeth with a razor blade and placing acrylic stains into these cuts. Surface stains are added by applying stain to the appropriate areas to simulate eroded areas or areas of incomplete calcification. Acrylic stains are available in such colors as brown, yellow, blue, orange, gray, and white and can be used in various combinations to give very pleasing and natural effects. After staining has been completed, the teeth may be replaced in the mold and covered with a thin layer of clear acrylic by adding clear powder and liquid. This layer of clear acrylic tends to give an appearance of depth to the stains. The mold is again closed with wet Cellophane and is boiled for a minimum of thirty minutes. The teeth are then removed, trimmed with sandpaper discs, and polished with pumice (Fig. 12).

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A STUDY OF THE TEMPOROMANDIBULAR JOINT VIEWED FROM THE STANDPOINT OF PROSTHETIC OCCLUSION

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THE temporomandibular joint and the associated musculature have been the subject of vast and intensive study for many years. Anatomic dissection, physiologic experiments in nerve and muscle stimulation, comparative observations of healthy, diseased, and malformed organs in the living body, and roentgenographic studies have yielded much valuable information. Yet, because of the very complex structural and functional mechanism of the joint, there are many areas in our knowledge which are painfully blank. Our inadequacy is especially high lighted when we are faced with the diagnosis of certain types of temporomandibular joint syndromes or incipient disturbances in function of the joint.

The purpose of this article is (1) to evaluate some of the long-accepted facts and statements about the joint; (2) to evaluate some of the techniques of study; (3) to establish a scientifically correct procedure for further study; and (4) to suggest the setting up of an orderly system for examination and diagnosis of joint complaints.

Before proceeding, it would be advisable to present a review of the salient features of the anatomy and physiology of the structures under discussion.

ANATOMIC CONSIDERATIONS

The temporomandibular articulation consists of the capitulum or condyle head of the mandible and the glenoid fossa of the temporal bone. The capitulum and the fossa are both covered with fibrocartilage. The capitulum is situated obliquely on the neck of the condyle in such a way that its lateral end is more forward than its medial end. The neck of the condyle is flat in the anteroposterior direction. Posteriorly it is convex, and anteriorly, on its medial aspect, it is hollowed out by a depression, the pterygoid depression, for the attachment of the external pterygoid muscle.

The lateral and medial margins of the neck of the condyle are narrow and present ridges that are a continuation from the sides of the capitulum. The lateral ridges of the neck give attachment to part of the temporomandibular ligament.

The Glenoid Fossa.—The glenoid fossa is a large oval hollow, bounded in front by the anterior eminentia articularis and behind by part of the temporal bone. The petrotympanic fissure divides this fossa into two portions: the anterior, which articulates with the condyle head of the mandible to form the

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temporomandibular articulation proper, and the posterior, which is occupied sometimes by a part of the parotid gland.

The anterior or mandibular cavity is situated in the inferior surface of the squama of the temporal bone. Its interior surface is formed above by the deepest portion of the fossa, anteriorly by the anterior eminentia articularis, posteriorly by the posterior eminentia articularis (postglenoid process, posterior lip), and medially and laterally by two short lips descending from the medial and lateral boundaries of the fossa.

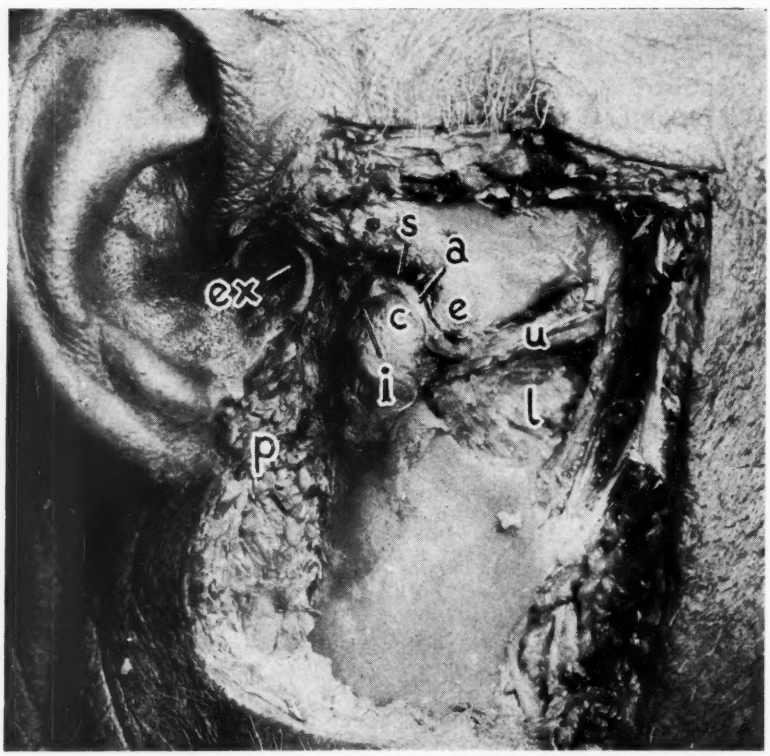

Fig. 1.—*e*, eminentia arcuata; *u*, upper head external pterygoid; *l*, lower head external pterygoid; *c*, condyle; *s*, superior joint cavity; *i*, inferior joint cavity; *a*, articular disc; *p*, parotid gland; *ex*, external auditory meatus. (Courtesy of Anatomy Department, New York University, College of Dentistry, New York, N. Y.)

The Petrotympanic or Glaserian Fissure.—This fissure runs in an oblique direction and transmits the tympanic branch of the internal maxillary artery and the chorda tympani nerve.

The auriculotemporal nerve also runs in close proximity to the temporomandibular articulation. This nerve usually arises from the posterior portion of the third division of the fifth nerve. From its exit through the foramen ovale it runs backward medial to the external pterygoid muscle to the inner part of the mandibular neck. It is here in close relation with the capsular ligament.

Articular Disc or Meniscus.—The articular disc is a plate of fibrocartilage, oval in shape. It is interposed between the condylar head and the mandibular fossa and is connected with the articular capsule at its circumference. It divides the joint into two cavities, superior and inferior, which are lined by a synovial membrane that is reflected from the capsular ligament. The lower cavity is the smaller of the two. This disc of fibrocartilage is thinnest at its center and thickest at the circumference. Its inferior surface, where it accommodates the condyle head, is concave. The superior surface is concave anteriorly and convex posteriorly and is in contact with the articular surface of the temporal bone.

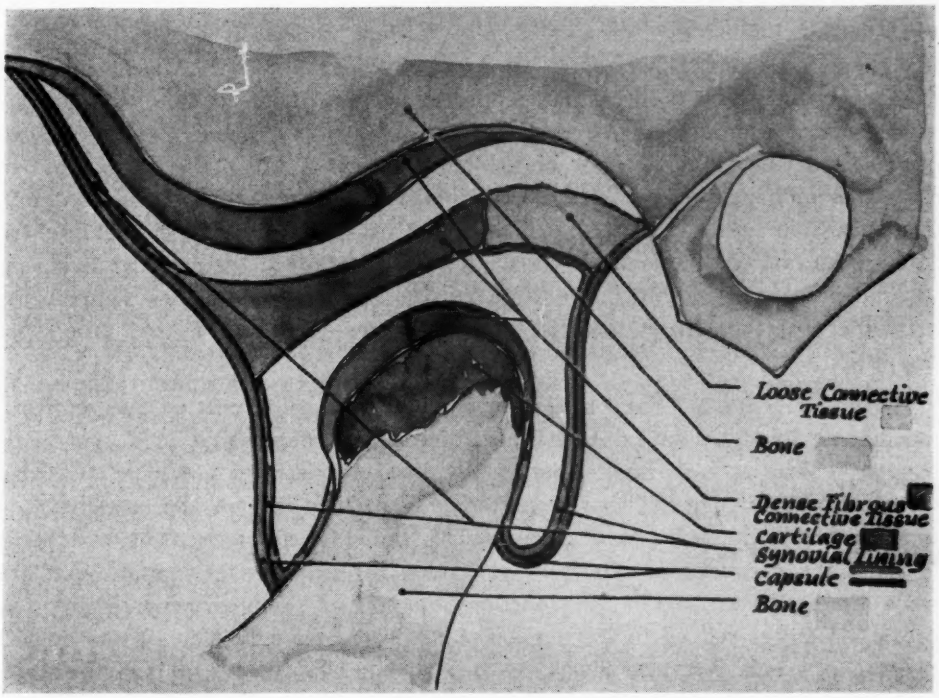

Fig. 2.—Diagram of the histology of the temporomandibular articulation. (Courtesy of Harry Sicher, M.D., Loyola University, School of Dentistry, Chicago, Ill.)

Ligaments.—The capsular ligament is a thin and loose sac which binds the bony margin of the mandibular fossa and condyle head together. It is attached above to the circumference of the mandibular fossa, to the zygomatic process of the temporal bone, and to the angular spine of the sphenoid bone. Below, it finds attachment to the neck of the condyle head of the mandible extending posteriorly upon the ramus.

The temporomandibular ligament is a short and thin fasciculus, situated on the lateral side of the articular capsule. It serves as a reinforcement for the capsular ligament and forms an inseparable union with it. Superiorly, it is attached to the external surface and lower edge of the zygoma and to the tubercle that forms the meeting point of the two roots of the zygoma. Inferiorly, it is attached to the lateral surface of the neck of the condyle.

The sphenomandibular ligament is a flat, thin, loose band, somewhat removed from the joint, medial to and slightly behind the capsule. It is attached above to the angular spine of the sphenoid bone and to a portion of the petrotympanic fissure. Below, it is attached to the lingula of the mandible.

The stylomandibular ligament is a specialized band of the cervical fascia, extending from near the tip of the styloid process of the temporal bone to the angle and posterior border of the ramus of the mandible, between the masseter and internal pterygoid muscles.

The Muscles of Mastication.—The muscles of mastication are the temporal, masseter, and internal and external pterygoids. For our present purpose we need consider only the external pterygoid in some detail. It is conical in form and runs in an almost horizontal direction; it consists of two heads, separated from one another by a slight cleft. The upper head takes origin from the inferior surface of the greater wing of the sphenoid bone, while the lower head originates at the lateral surface of the lateral plate of the pterygoid process of the sphenoid bone. The two run horizontally and laterally to be inserted into the depression in the anterior portion of the neck of the condyle and into the anterior portion of the meniscus via the anterior portion of the capsular ligament.

The digastric, stylohyoid, geniohyoid, and mylohyoid muscles depress the mandible when the hyoid bone is fixed, and they take part in the process of deglutition.

Muscle Activity.—The muscles that control the movement of the temporomandibular joint are an excellent illustration of a group acting in a synergistic manner. That is, no muscle operates by itself to perform a simple or single movement. Although each has been studied in isolated fashion, the movements in function involve interplay of all the muscles. However, the movement we observe is often the resultant of divergent action of several muscles operating at the same time. Since isolation in function is impossible, impairment of any one of the structures related to the temporomandibular joint adversely affects the entire group. This fact must always be kept in mind in our researches into health and disease.

DISCUSSION

The approach to the study of the joint has in the past been a mechanistic one. That is to say, the anatomic findings in all their minutiae were the basis of explanations of the parts in function. Likewise, the behavior of a part in function was studied by dissection without regard to its relation and integrated action with the other parts. For example, for a long time it was not fully realized that the function of the temporomandibular joint and the occlusion of the teeth are inseparable, constituting one indivisible entity, the masticatory apparatus. They are as inseparable and interdependent in producing smooth and effective function as the front and rear wheels of an automobile are in producing a smooth ride. The interdependence, interaction, and mutual reciprocity of all the structures of a functioning organism are the most essential features to understand if one is to interpret the manifestations of life and disease.

The dental profession has regarded the temporomandibular joint as consisting mainly of a bony condyle head and bony glenoid fossa, assuming that the activity of the joint in life is almost the same as seen in the skull. Hence, measurements of the inclined plane of the eminentia articularis have been calculated geometrically with the objective of finding the so-called average condylar path. Some dentists have gone so far as to reproduce condyle heads and glenoid fossae in metal for the construction of so-called anatomic articulators. Mandibular movements in horizontal and vertical directions have been analyzed and their resultant directions calculated from a strictly geometric point of view. This has led us to speak in terms of centers and spheres around which the mandible moves along predetermined and preconceived pathways, as if the joint with its muscles, ligaments, tendons, and synovial membranes were a geometric figure and not a living organ.

This mechanistic background has governed also the study of disturbances of the temporomandibular joint and associated structures, leading to many speculations. For instance, it has been claimed by many clinicians that perforation of the articular disc is responsible for many cases of joint syndromes. In the Department of Anatomy at New York University, College of Dentistry, however, 1,000 discs of cadavers were examined, and only one was found to be perforated. Anatomy textbooks do report that, at times, lack of continuity or perforation of the disc is observed, but this is frequently the result of developmental anomalies. Yet some clincians go so far in their speculation as to state that certain positional relationships of the condyles in their respective glenoid cavities (as observed in roentgenograms) may cause an abnormal condition by perforating the disc only. They feel that if the condyle head, upon opening of the jaw, moves more forward than they believe it should, the potentiality for perforation of the disc exists. On roentgenographic grounds that are entirely speculative, they are then invariably inclined to suggest a diagnosis of possible perforation of the disc.

Such conclusions are scientifically invalid for two reasons:

1. There is no established ratio between the opening component and the respective rotation of the condyle head forward; it varies greatly in different individuals.

2. Our x-ray technique and x-ray interpretation of physiologic movements of the condyle head are so grossly inadequate and misguided as to require complete reorientation.

Let us consider these two points in some detail. For the last three decades no attempt has been made to differentiate between a strictly rotational movement of the condyle in the glenoid fossa, associated with a strict opening component, and a rotatio-gliding movement of the condyle that results from a combination of an *opening component* with an *opening protrusive component.* As a matter of fact, the state of confusion is so great that the *opening protrusive component* is always interpreted in our dental literature as being a strictly *opening component.* Yet the two are vastly different from one another. To avoid misunderstandings, a few preliminary remarks relating to the physiology of the joint are in order.

Any movement of the mandible, in whatever direction, is not caused merely by a pull of one muscle or a group of muscles in the particular direction. Rather

it is effected by pulls of muscles in various, and at times in opposite, directions with a view of creating a perfect balance for the intended *resultant movement.* The latter, in direction and magnitude, represents, therefore, the final product of muscular activity of various muscles working in coordination and in perfect harmony. This muscular coordination and balance is so fine that it does not lend itself to measurement by our finest instruments. Let us consider the hinge movement, otherwise called the up-and-down movement, the opening component

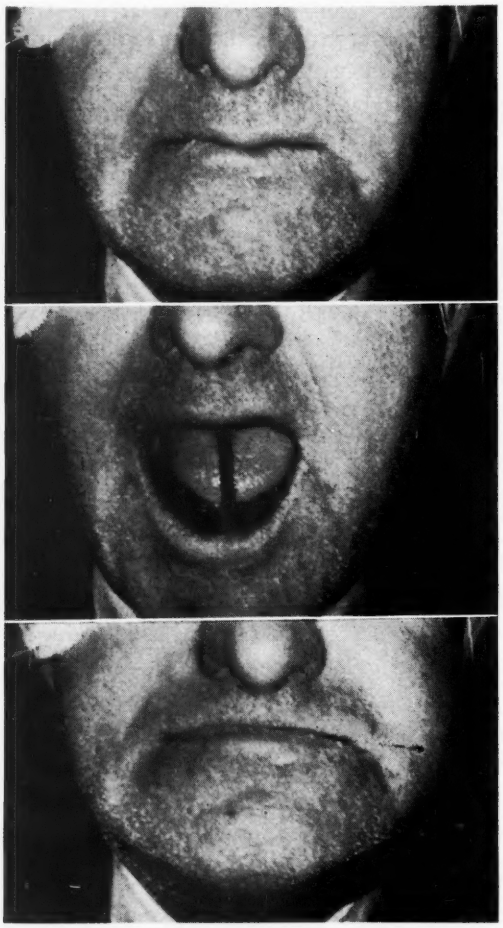

Fig. 3.—*A*, Mouth closed in unstrained centric occlusion with artificial dentures (see Fig. 4*A*), *B*, Mouth open the orthodox way by interposition of block of wood 30 mm. in lenth (see Fig. 4*B*). *C*, Mandibular overclosure. Shellac baseplates 2 mm. each in thickness in contact anteriorly (see Fig. 4*D*).

movement, and the ginglymoid movement. None of these terms truthfully expresses the complexity of movement that actually takes place. It has been thought that this particular movement is exclusively rotational in character and takes place in the lower glenoid cavity only. A careful clinical and roentgenographic study shows this not to be the case. No condylar movement, small in scope as it may be, is ever entirely confined to one cavity exclusively. Nor could it be entirely

reduced to a simple linear or rotational movement. It is always a *combination* of rotation and gliding. And it is only the extent or degree of predominance of certain muscle activity in a certain direction that makes us speak of a movement as being either predominantly rotational or gliding in character. However, to be practical we must commence our studies with an analysis of the basic fundamental principles relating to jaw movements.

In the roentgenographic procedures used in study of the physiology of the joint and in the practical application of the same procedures in the diagnosis of temporomandibular joint disturbances, it has somehow come to be generally accepted that it is sufficient to secure two x-ray exposures of the joint, one with the jaws in "centric occlusion," the other with a jaw separation in the incisor region equal to 30 to 35 mm., which is captioned in our literature as the opening component or, simply, jaws open.

Not only are two views of the joint insufficient to tell us anything about it in function, but, also, the manner in which these views have been obtained is so full of errors as to render them interpretively useless.

The closed mouth position used in the orthodox procedure of temporomandibular joint roentgenography for diagnostic purposes is unscientific. The patient is instructed by the dentist, or more often by the x-ray technician, to close the mouth with the words "close tightly," or "clench your teeth," without any regard for the laws governing centric occlusion and centric jaw relations and without consideration for the maxillomandibular opening or the peculiar pattern of occlusion that the patient possesses at the particular time when the roentgenograms are taken. Three possibilities may arise: (1) The patient may close tightly in any of the eccentric occlusions instead of centric. (2) The anteroposterior and lateral relation of the mandible to the maxilla may be correct but the occlusion strained. As a matter of fact, the occlusion, in these instances, is always strained, since the patient is instructed to keep the jaws tightly closed. (3) The patient may close in an acquired habitual occlusion. Little consideration, or none, is attached to the very important factor of *habitual dynamics* of a particular occlusion resulting from a process of development peculiar to this individual. We are still tightly attached to and entangled in the traditional concept of *perfect static anatomic occlusion.* But in diagnosis of temporomandibular joint dysfunction, this antiquated concept is even less applicable than in other phases of diagnosis in dentistry. This is so because in most instances of temporomandibular joint disturbances we are confronted with the presence of a pathologic pattern of occlusion of one kind or another that constitutes the cause of disturbance. Thus we see that when the patient is instructed to close the mouth, he closes not into a correct centric, static occlusion, but into a pathologic pattern of centric occlusion, his affliction at the time.

The second static exposure to which the joints are subjected is the so-called "open mouth exposure." The method most widely used by roentgenologists and general practitioners alike for setting the jaws for this purpose consists in placing a block of wood or a block of processed plastic material between the incisal edges of the upper and lower incisor teeth so that the distance between these

Fig. 4*A*.—Artificial full dentures. Unstrained centric occlusion associated with unstrained centric jaw relation. Distance between ridges is 28 mm. Note the position of the condyle head in the glenoid cavity in static centric occlusion of artificial dentures.

Fig. 4*B*.—"Mouth open" the orthodox way 30 mm. by insertion of block of wood 30 mm. long between the incisal edges of the upper and lower artificial dentures. Note the considerable forward shift of the condyle heads with the so called "mouth open" exposure. In reality this represents a combination of an opening component and protrusive component with the admixture of a slight lateral component.

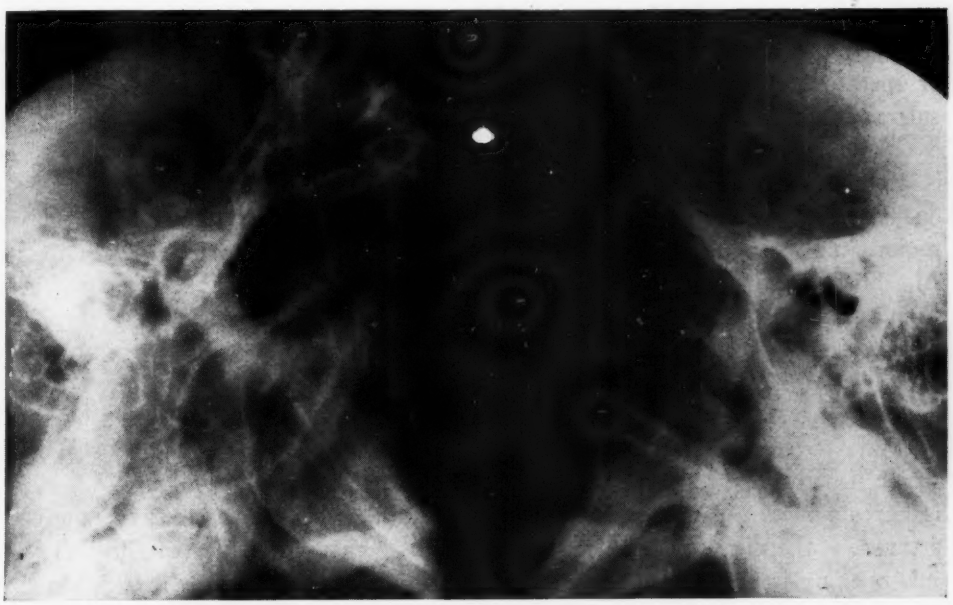

Fig. 4*C*.—A rotational opening component of 28 mm. secured by a prosthetic record as described in the technique. Note the difference in the position of condyles in this exposure as compared with the preceding one. Here with an opening component of 28 mm., the condyle heads still remain within the boundary of their glenoid cavities.

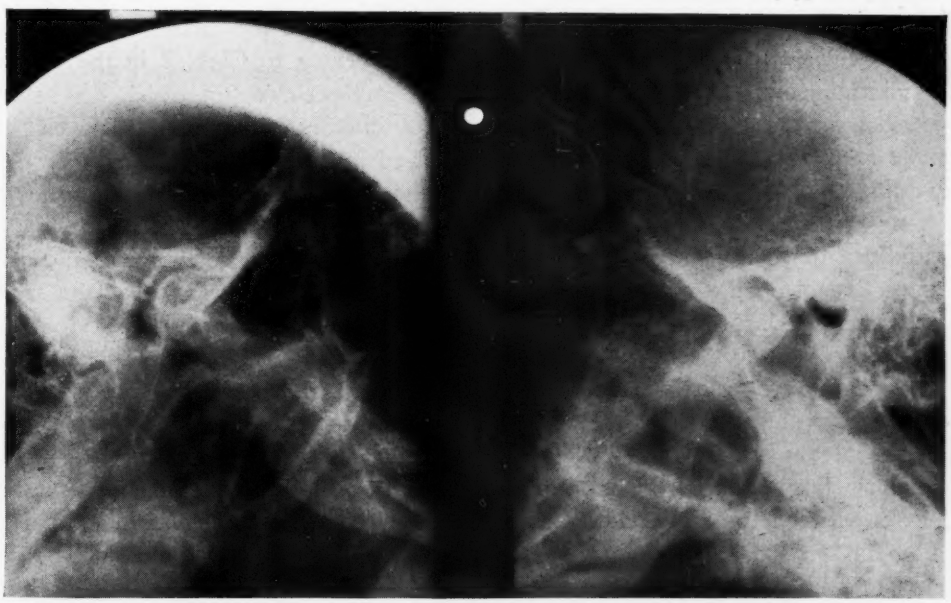

Fig. 4*D*.—Overclosure with a 4 mm. distance between the ridges anteriorly. This exposure was secured by having the patient close the jaws with upper and lower shellac baseplates in contact anteriorly. Each baseplate measured 2 mm. in thickness anteriorly. Note, though the gonions moved perceptibly forward, the condyle heads did not encroach upon the tympanic plates of the temporal bone.

incisal edges is approximately 30 to 35 mm. It has been accepted, somehow, that the average maxillomandibular opening component is equal to 35 mm. A number of operators, while not disputing the validity of the 35 mm. average, have considered it more convenient in their own work to use an average opening component of 1¼ inch or approximately 30 mm. To use such average figures routinely is obviously unscientific and incorrect, for many studies have shown that jaw opening distances range between approximately 20 and 60 mm. in the incisor region in individuals with a fully developed temporomandibular joint anatomy. In addition, measurement of the opening is complicated by the fact that these openings are not pure opening components but a combination of opening and protrusive components. We know, by clinical observation and roentgenographic investigation, that each individual is endowed with two main types of jaw opening. The first one, ranging between 15 and 25 mm., may be designated for practical purposes of study only as the rotational opening component. The second opening, which usually follows when the individual is asked to open his mouth still wider, is accomplished by the external pterygoid muscle assuming the leadership with a thrust of the mandible downward and forward. It then follows that the 35 mm. jaw opening is usually a combination of an opening component with a protrusive component. This is further complicated by the fact that the relative ratio of these two components varies greatly in different individuals.

A second source of error in this method arises from the fact that the instruction to the patient to bite on the block tends to provoke a protrusive-incisive movement of the mandible. This protrusion of the mandible is also caused by the necessity of the patient to balance the block between the incisor teeth. This is particularly true in patients whose occlusions belong to Class 2 in the Angle classification or its equivalent; that is to say, any occlusion in which the lower incisors are situated distally from the upper incisors. In these instances, in most roentgenograms which have been captioned in our literature "mouth open," we find the condyle heads migrating up to the lowest point of the eminentia or even slightly in front of it, whereas with a scientifically correct "mouth open" exposure the condyle heads should remain predominantly confined within their respective glenoid cavities. The reason for this lies in the fact that the true opening and closure path is mostly controlled by the ginglymoid movement in the lower cavity. As long as the opening and closure paths are predominantly rotational in nature, the condyle heads will not leave their respective sockets. As soon as we get a gliding or arthrodial movement, the condyle heads commence to migrate in the direction of the lowest point of the eminentia. Setting the condyles for the "mouth open" exposure by means of wooden or hard plastic blocks between the incisor teeth introduces movements other than the rotational. This makes the roentgenogram interpretively useless, because it represents a combination of ginglymoid and arthrodial movements in unpredictable directions and of unpredictable magnitude.

Furthermore, there will be a tendency on the part of the patient to move the mandible to the right or left side, depending upon whether the operator is holding the block to the right or left side when the patient is instructed to bite

on it. The magnitude of each of these movements is also unpredictable, because the patient will automatically move the mandible in directions the resultant position of which is best suited to grasp and hold the block firmly.

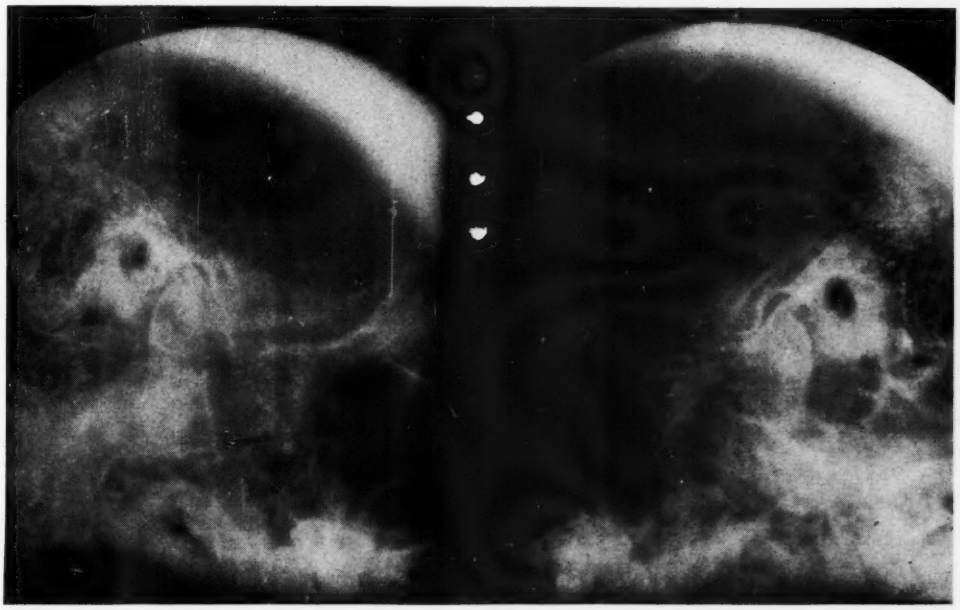

Fig. 5*A*.—Natural dentition, centric occlusion associated with centric jaw relation.

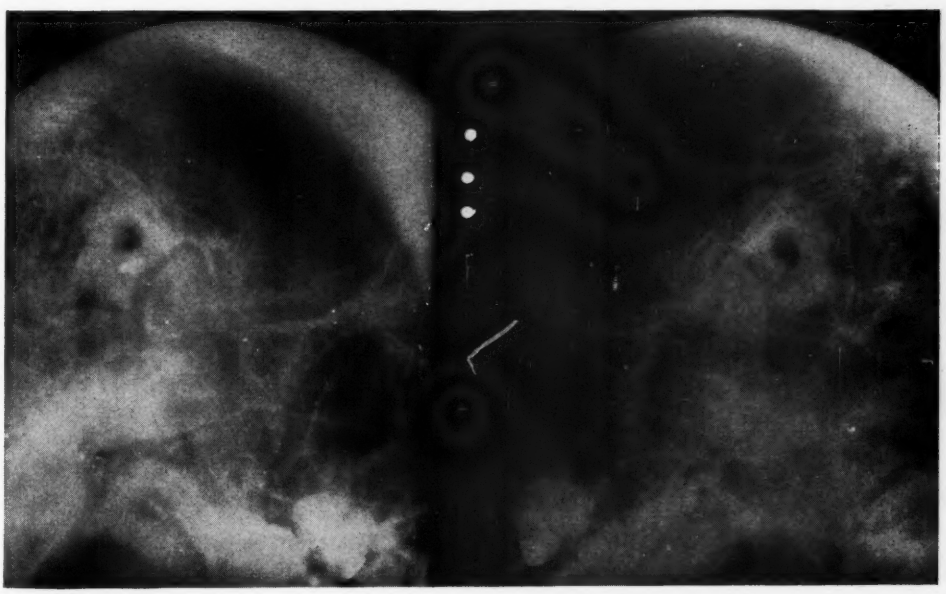

Fig. 5*B*.—An unstrained rotational opening component of 9 mm. between the incisal edges of the upper and lower central incisors. Condyle heads did not perceptibly change their position compared with the preceding exposure with intercuspation of teeth in centric occlusion.

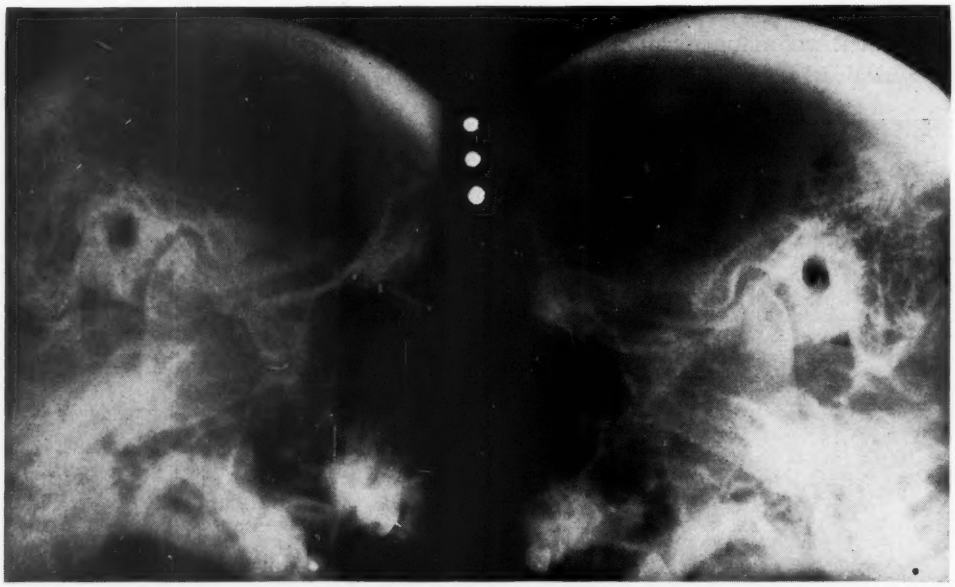

Fig. 5*C*.—A 15 mm. rotational opening component. This exposure was obtained with a wax record measuring a distance of 15 mm. between the incisal edges of the upper and lower anterior teeth.

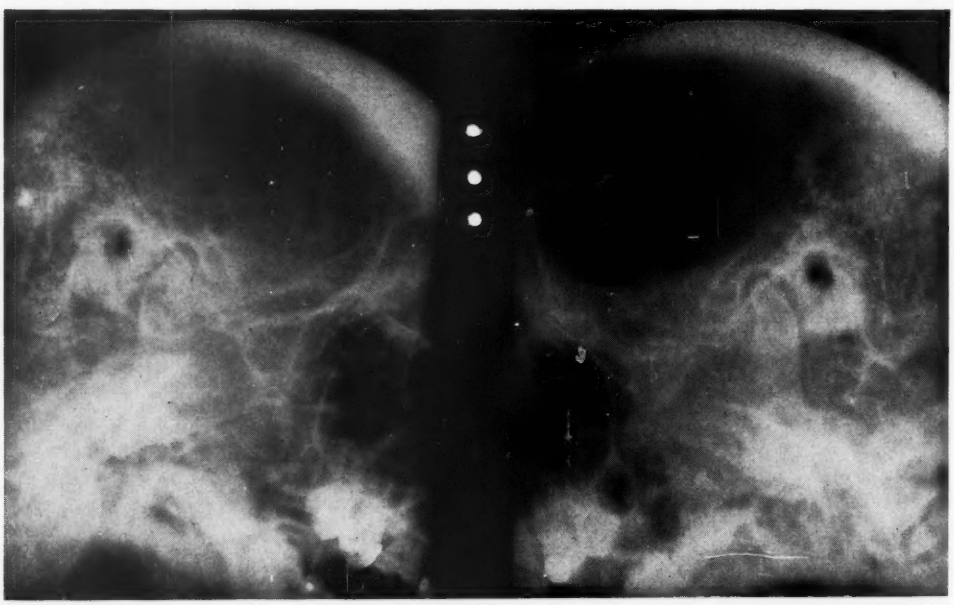

Fig. 5*D*.—This exposure was secured with a wax record measuring a distance of 24 mm. in between the incisal edges of the upper and lower anterior teeth. On careful examination of the four exposures of this series one realizes that roentgenograms are of little assistance in the determination of the maxillomandibular opening. The latter is strictly a clinical procedure. Statements to the effect that "the roentgenogram shows that this bite can be opened or closed 2 mm." are unscientific and invalid. As we can readily see in each of these four exposures, the condyle heads remain within the confines of their respective glenoid cavities.

Finally, we cannot, in this method, control the magnitude of forces that the patient introduces. One patient may bite on the block with considerable force, while another may press very lightly, depending upon the feeling of security he experiences in his endeavor to maintain the block in place. Strained relations may result from forceful biting on the block. It should be fully realized then that the so-called "opening component" of the mandible to the maxilla that is now being established in the orthodox way, by biting on a block of wood, does not in reality represent an opening component at all. What it most frequently represents is a combination of three components: opening, protrusive, and lateral. And the ratio between the individual components in these combinations is subject to a wide range of variation, depending upon the peculiar anatomic and functional characteristics of the case on hand.

Fig. 5*E*.—A 30 mm. "mouth open" exposure the orthodox way. This exposure was secured by inserting a block of wood 30 mm. long between the incisal edges of the upper and lower anterior teeth. The patient is instructed to bite on it. Note the considerable displacement of the condyles forward in this procedure. Obviously, this is not a rotational opening component but a combination of several movements in various directions. The magnitude and direction of these movements are uncontrollable and unpredictable. The method is, therefore, unscientific.

Since all these factors tend to render the orthodox method of temporomandibular joint roentgenography unscientific and unreliable for diagnostic purposes, it should be fairly obvious that a correct temporomandibular joint diagnosis cannot be arrived at on the basis of these two faulty exposures. The first one, mouth closed, may represent a malrelation of the mandible to the maxilla that is inherent in the patient's particular pathologic pattern of occlusion at a given time. The second, mouth open, usually represents a malrelation of the mandible to the maxilla into which the patient was misdirected by the operator.

On the basis of such roentgenograms, devoid of any scientific validity, diagnoses of joint disturbances are established and treatment planned. The condyles are allegedly found to be in a superior or inferior, anterior or posterior position from where the operator would have them in accordance with his preconceived idea of normality. One condyle head is allegedly in front of the other or "slightly" to the back because the operator confuses the opening component with a lateral movement. Or else one condyle head may be found to be inferior or superior to the other, as if normally the two condyles are always to be found geometrically in the identical position. If the condyle heads are found to be (with "mouth open") in front of the eminentia articularis, it is concluded that we are dealing with a case of dislocation. However, a careful scientific investigation along these lines shows that in a great number of cases in which the condyles are in front of the eminentia no symptoms whatsoever are manifest, and no disturbance of function is apparent (see Fig. *7B*). If only one condyle head is found to be in front of the eminentia, a diagnosis of a unilateral dislocation is made. Actually this, too, is frequently a misdiagnosis and in many instances represents a lateral associated with a protrusive movement with complete absence of any symptoms. When one condyle head is found to be in front of the other, within the range of the glenoid cavity itself, the condition is frequently diagnosed as a *unilateral subluxation.* In many instances, this, too, is a misdiagnosis and actually represents a small range lateral relation of the mandible to the maxilla with the absence of any symptoms. As pointed out earlier, some operators even claim that they can clearly see and interpret on the roentgenogram such conditions as perforation of the disc or a torn ligament.

Generally speaking, the term subluxation covers a multitude of symptoms relating to the temporomandibular joint syndromes. According to accepted definitions, a subluxation is a partial dislocation. Dislocation, as applied to the temporomandibular joint, implies a slipping out of the condyle head from the boundaries of the glenoid cavity, supposedly due to a loosening of the muscles and ligaments that control the joint. Clinically, subluxation is characterized by a restriction of movements of the condyles in their cavities to a degree less than normal. Since dislocation is characterized by a loosening of the muscles and ligaments of the joint and subluxation by a tightening of the same tissues, one wonders how subluxation can be defined as a partial dislocation. One also wonders how the same mode of treatment (injection of sclerosing solution) can be advocated for both of these conditions.

We all can read and interpret pathologic conditions relating to bone formation and bone resorption, such as partial or complete ankylosis, erosion of the condyle head, or a fracture of the condyle head, but most pathologic conditions that reside in the soft tissues of the joint cannot be diagnosed roentgenographically at the present time. The temporomandibular joint, due to its anatomic peculiarities (condyle within a deep bony cavity), represents great difficulties from a roentgenographic standpoint. No matter what our approach is and under what angulation we secure these roentgenograms (with the present state of our knowledge), some superimposition of bone is inevitable. This alone greatly reduces the value of these

roentgenograms for diagnostic purposes. Secondly, the soft tissues in and about the joint, the disc, ligaments, synovial membranes, and so forth, appear in the roentgenograms as one radiolucent mass. Since we have not been successful as yet in isolating these structures by means of staining or injection of radiopaque substances in the living, it is increasingly difficult to study their behavior individually in health as well as in disease.

The securing of a roentgenogram, which is essentially a shadow picture, involves three requirements: (1) a source of radiation, (2) a screen or film for the reception of the image desired, and (3) an object, the image of which is to be reproduced.

Regrettably, the last of these factors is being mismanaged by us in our temporomandibular joint roentgenography, the object, in this case the condyle head. As has been pointed out, the positioning of the mandible for temporomandibular roentgenography does not rest on a scientific basis. The condyle head in closed and open mouth exposure (when taken the orthodox way) is malpositioned. Furthermore, for the last three decades we have relegated the positioning of the mandible to the maxilla (for temporomandibular joint roentgenography) to x-ray technicians. The latter, not having had training in occlusion, cannot position the mandible to the maxilla properly. Dentists have not fully realized how important this phase of the work is and have not taken the trouble to do it themselves.

Clearly then, we are in need of a standardized scientific procedure for temporomandibular joint roentgenography that would produce uniform results, films that every dental student and every general practitioner would be able to read, understand, and interpret. In order to overcome some of these inadequacies in temporomandibular joint roentgenography, a new and more careful technique should be employed. The technique to be described, based on the latest and most advanced concepts of prosthetic occlusion, offers an orderly procedure for research and examination by eliminating the defects and distortions inherent in the old technique. It claims no cure for temporomandibular joint disturbances, but marks, we believe, a step forward in this field of research.

DESCRIPTION OF TECHNIQUE

1. Secure a set of upper and lower impressions in alginate material as carefully as possible and pour casts. (a) Mount the upper cast on an adjustable articulator by means of a face-bow. (b) Carefully secure an unstrained centric relation record and attach the lower cast to the articulator. (c) Set the articulator for lateral and protrusive movements with a view to making a careful survey and analysis of the patient's dynamic occlusion. (d) Study and compare the occlusal contacts of teeth on the articulator when in centric and eccentric occlusions with the corresponding contacts of the teeth in the mouth in functional occlusions. (e) Get a good general mental picture of the anatomic, biologic, and dynamic conditions under which the masticatory apparatus is functioning.

2. Secure an unstrained centric jaw position and instruct the patient to maintain it without pressure. Make the first temporomandibular joint exposure.

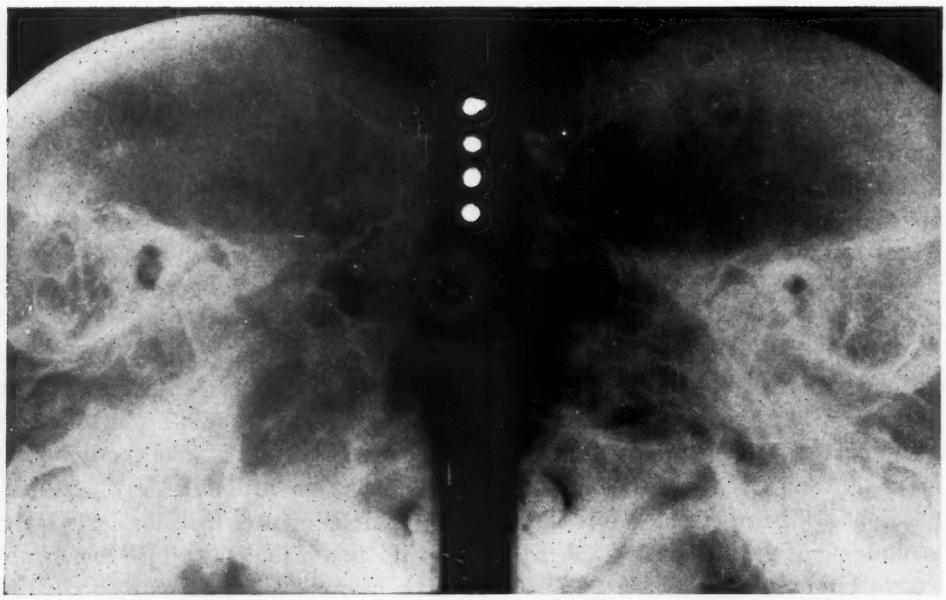

Fig. 6*A*.—Natural dentition, unstrained centric occlusion associated with unstrained centric jaw relation. Note the position of the condyle head in the glenoid cavity when the teeth are in static centric occlusion.

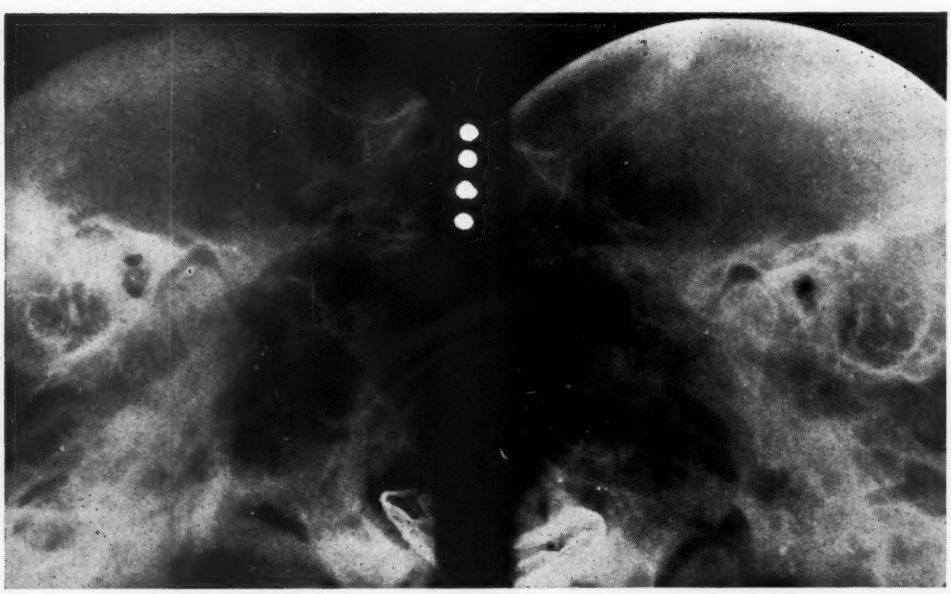

Fig. 6*B*.—Unstrained rotational opening component of 4 mm. Note the position of the condyle head in the glenoid cavity with this jaw separation.

3. Lock the articulator to prevent the possibility of any movement except along the opening and closing paths.

4. Cover the occlusal surfaces of the casts with a fine layer of talcum powder, place a roll of wax, 6 mm. in thickness, between the upper and lower teeth, and

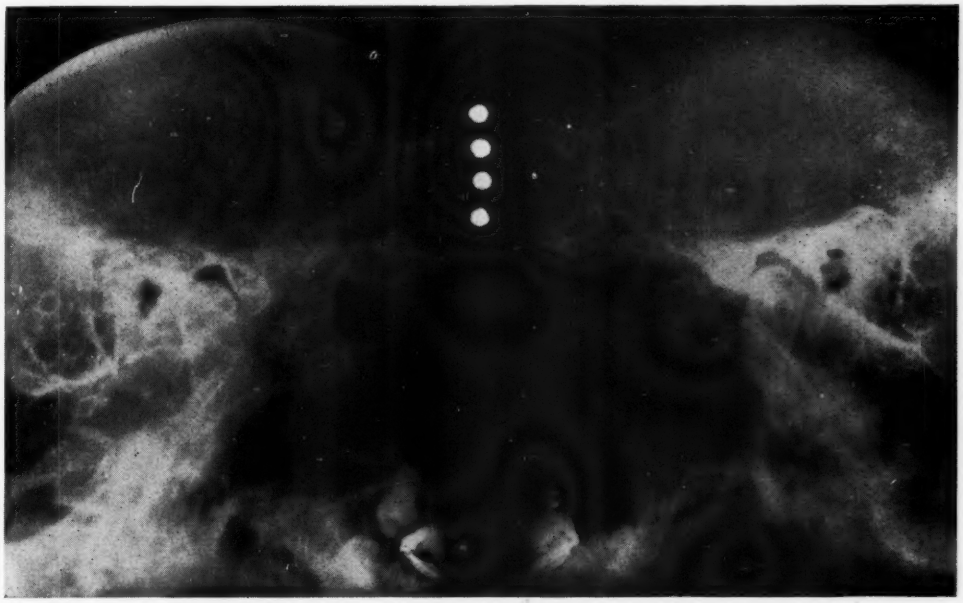

Fig. 6*C*.—Unstrained rotational opening component of 10 mm. Note the position of the condyle head in the glenoid cavity with this jaw separation.

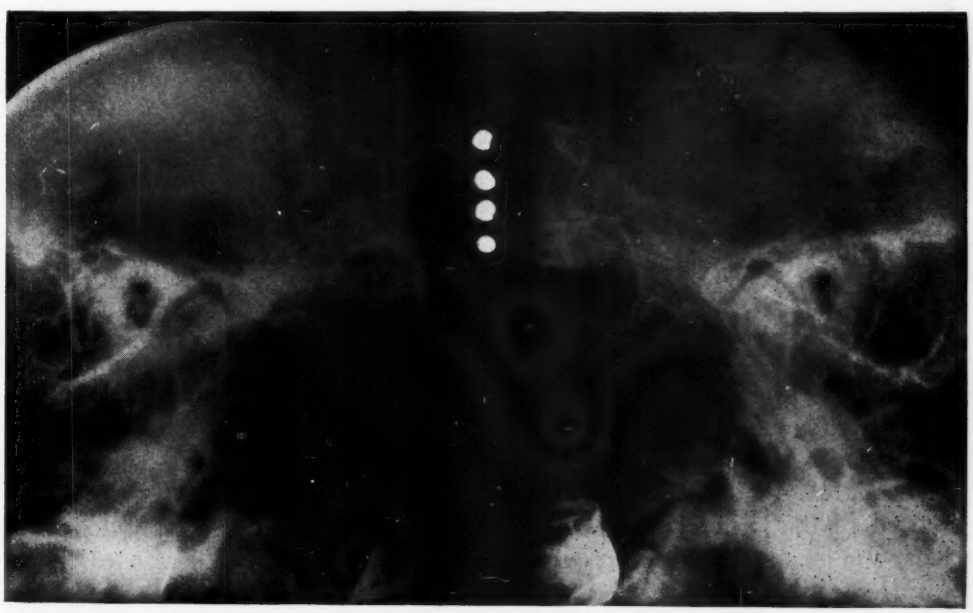

Fig. 6*D*.—Unstrained rotational opening component of 31 mm. Note the position of the condyle head in the glenoid cavity with this jaw separation.

close the articulator forcing the teeth into the wax to the depth of 2 mm. Chill the wax check bite with a blast of cold air and cut away any guiding inclined planes that may be present on its undersurface with a sharp knife. Introduce it now into the patient's mouth by placing it first against the occlusal surfaces of the upper teeth and have the patient close carefully along the individual closure path into this wax check bite.

If this contact in the mouth is identical with the one on the articulator and the patient feels perfectly comfortable, we conclude that the opening component of the articulator and the opening path of the mandible run along the same lines.

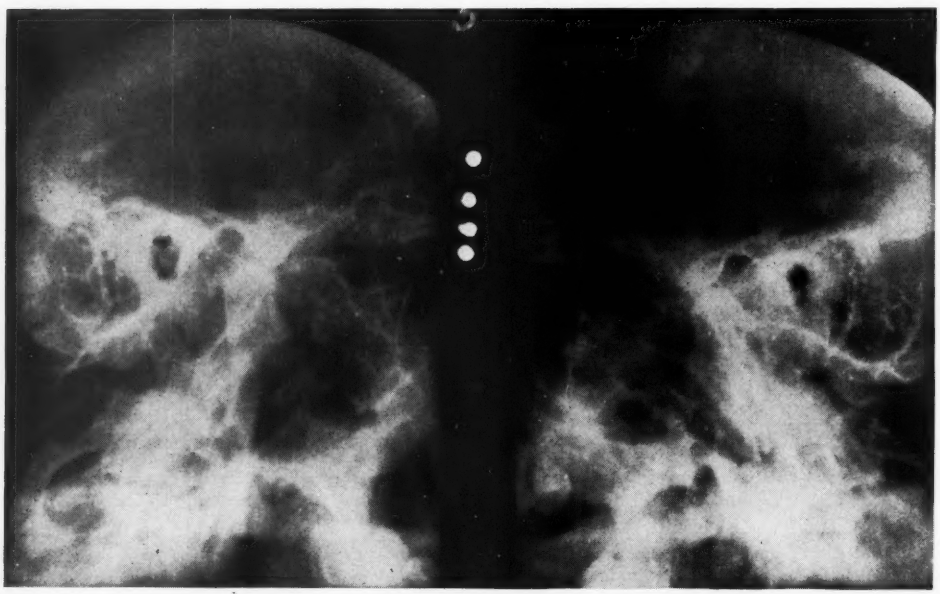

Fig. 6*E*.—Rotational opening component of 30 mm. This exposure was secured the orthodox way by interposing a block of wood 30 mm. long between the incisal edges of the upper and lower anterior teeth. Note the forward displacement of the condyle heads in this exposure as compared with the position of the condyles in Fig. 6*D* representing a rotational opening component of 31 mm. Obviously, the so-called "mouth open" exposure the orthodox way is an uncontrolled and unpredictable displacement of the mandible in various directions.

However, if a slight discrepancy is discernible, the lower surface of the wax check bite should be reheated by lightly brushing it over with a blowtorch flame or by submerging that surface into warm water for several seconds. Reintroduce the wax into the mouth and have the patient close carefully and lightly into the reheated lower surface. Chill the corrected check bite and check it by having patient open and close several times. If the teeth fall into the same position and the relation is not in the least strained, we conclude that we have now obtained a 4 mm. opening component and are ready for the second exposure. Chill and reintroduce this wax check bite into the mouth and instruct patient to close gently and maintain this closure without strain until exposure is completed. We now have a roentgenographic record of a 4 mm. opening component of the temporomandibular joints.

5. We can now proceed with preparations for the third exposure. For that purpose we place a roll of wax, 12 mm. in thickness, between the upper and lower occlusal surfaces of the teeth on the articulator and close it into the wax to the depth of 2 mm. Chill this wax check bite with a blast of cold air, remove it from the articulator, and carefully shave off excess inclined planes on the lower surface and excess wax from the labial, buccal, and lingual surfaces of the wax check bite. Remove it carefully from the articulator and introduce it into the mouth. If the natural teeth fall into the pattern formed by the occlusal surfaces of the lower teeth on the articulator, if there is no strain whatsoever discernible, and if the patient's tactile sense is also free from strain, we conclude that the opening path of the 10 mm. space in the mouth and the opening component along the same distance on the articulator are, for practical purposes, the same. If, on careful checking, a discrepancy is disclosed, correction is made in the same manner as for check bite No. 1. When correction is completed, the 10 mm. opening component wax pattern is introduced into the mouth, the patient is instructed to close gently and maintain this unstrained occlusion, and the third temporomandibular joint exposure is made.

6. A 20 mm. opening path wax check bite is prepared in a manner similar to the one for the 10 mm. opening path, and a fourth temporomandibular joint exposure is secured under conditions similar to the ones employed for the third exposure. An attempt is now made to secure a fifth temporomandibular joint exposure with a 25 to 30 mm. opening path wax check bite. Difficulties may now be anticipated as the opening path for this distance on the articulator may differ greatly from the one observed in the mouth. The jaw may now tend to move in a forward direction in an effort to accommodate the third 10 mm. portion of the 30 mm. opening component and may become strained and unbalanced. In this event, the fifth exposure is to be dispensed with because a temporomandibular joint exposure for the opening component becomes interpretively useless just as soon as admixture of a protrusive movement or a strained relation creeps in.

7. (a) We are now ready to proceed with the study of the protrusive paths of the condyle heads in their respective fossae. To accomplish this, we place a block of wood 3 mm. in thickness on either side between the shaft representing the articulator axis of rotation and the anterior stops. Both the horizontal slots and the vertical posts on the articulator should be set at zero degrees. This means that the articulator has performed a 3 mm. protrusive movement. We now place a soft roll of wax, 4 mm. in thickness, between the occlusal surfaces of the upper and lower teeth and close the articulator to the depth of 2 mm. There should remain a thickness of 2 mm. of wax between the occlusal surfaces of the upper and lower teeth. Chill the wax with a blast of cold air, carefully remove it from the articulator, and shave off the guiding inclined planes on the lower surface of the wax check bite as well as any surplus of wax from the labial, buccal, and lingual surfaces.

Introduce the wax check bite into the mouth by placing it first on the upper teeth and guide the patient's mandible to closure in the same protrusive relation without strain. Instruct the patient to maintain this protrusive occlusion

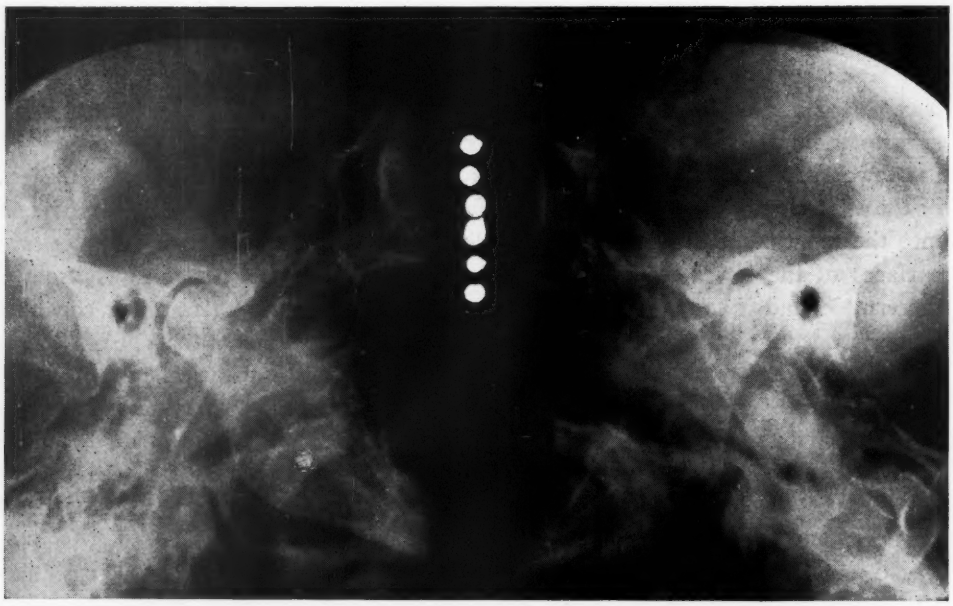

Fig. 7*A*.—Artificial complete dentures. Artificial dentures closed in centric occlusion. The distance between the ridges anteriorly is equal to 22 mm. Note the position of the condyles in their respective glenoid cavities at this maxillomandibular opening.

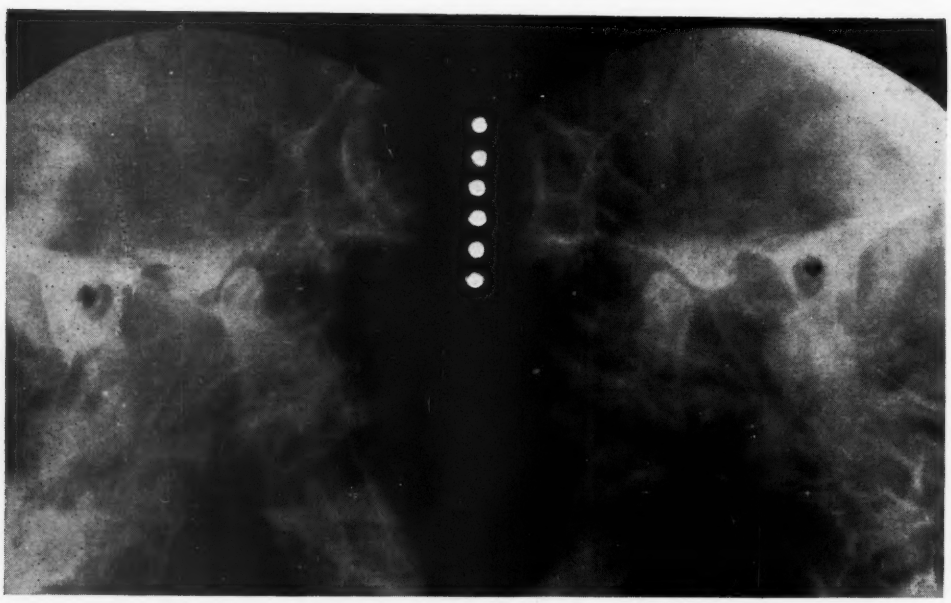

Fig. 7*B*.—Open the orthodox way 30 mm. by placing a block of wood 30 mm. long between the incisal edges of the upper and lower anterior teeth. Note the extreme protrusive displacement of the condyle heads. This roentgenographic view suggests mandibular dislocation, but the patient never experienced any difficulty. Clinical examination did not disclose any clicking or crepitation. This indicates that dislocation is not so much due to a particular anatomic static position of the condyle head in front of the eminentia articularis, but rather that it is caused by a spasmodic contraction of the external pterygoid muscles. We have many cases such as these on record.

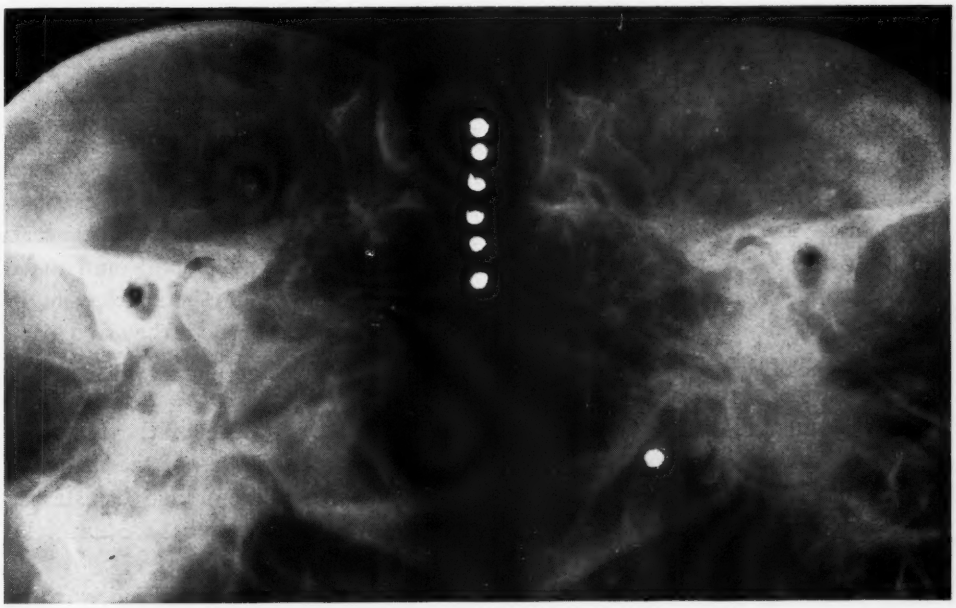

Fig. 7*C*.—Rotational opening component with distance between the incisal edges of the anterior teeth equal to 22 mm. Note the position of the condyles in this roentgenogram as compared with Fig. 7*B*. The comparison indicates that the orthodox so-called "mouth open" exposure is in reality an opening component combined with a protrusive and not infrequently with a lateral displacement of the mandible.

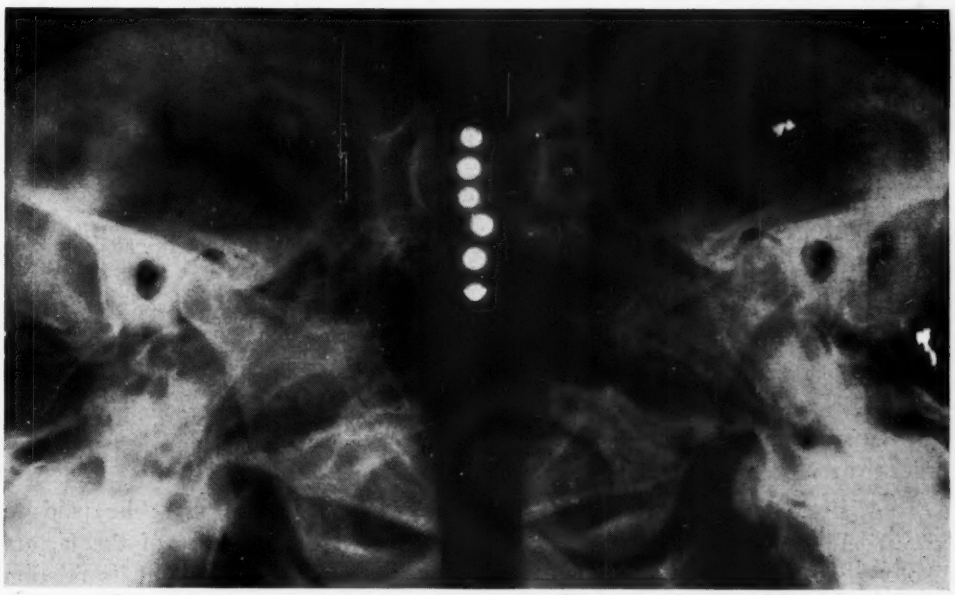

Fig. 7*D*.—Mandibular overclosure. This exposure was secured with two shellac baseplates in the patient's mouth making contact anteriorly. The thickness of each baseplate in this region was about 2½ mm. It is a strictly rotational overclosure component. The roentgenogram does not show evidence of closeness between the condyle head and tympanic plate of the temporal bone to justify claims of causation of deafness on this ground.

without strain and secure the first exposure of the temporomandibular joints in this protrusive relation.

(b) To prepare for the second protrusive exposure, place a block of wood, 5 to 6 mm. thick, on either side of the shaft representing the articulator axis of rotation. Place a roll of wax, 4 mm. thick, between the occlusal surfaces of the upper and lower teeth and close the articulator to the depth of 2 mm. Chill the wax check bite with a blast of cold air and shave off the guiding inclined planes of its lower surface as well as any excess of wax from the labial, buccal, and lingual surfaces with a sharp knife. Introduce it into the mouth and make sure that the lower teeth fall into the lower surface of the wax check bite in the mouth exactly as on the articulator. If corrections are needed, they are made in the same manner as previously described for the opening path check bites. We now instruct the patient to keep the mouth closed in this protrusive relation without strain and secure the second protrusive path exposure of the temporomandibular joints. Right and left lateral occlusions and relations of the mandible to the maxilla are secured in a similar manner on the articulator and transferred without strain into the oral cavity. All these wax check bites are carefully wrapped up with tin foil and kept as permanent records.

Roentgenograms taken in this manner for the study of the opening paths of the mandible as well as those secured for the excursive paths can be easily and scientifically superimposed upon one another. All factors remaining identically the same, one wax pattern is carefully removed after the exposure is completed, and the next one is carefully placed in the mouth (without any change in the head position) and followed by the next exposure. Guesswork is eliminated with this technique as we have permanent records for placement of the mandible into exact and unstrained occlusions associated with unstrained relations of the mandible to the maxilla.

CLINICAL DIAGNOSIS

Now recognizing the paucity of accurate knowledge and the abundance of speculation that exists in the field of temporomandibular joint roentgenography, we must realize the great importance of and depend heavily upon clinical diagnosis in the management of disease syndromes of this joint.

1. In order to aid in correct diagnosis of any disease, a detailed history of the patient's life and environmental background is important. It is also necessary to elicit as much information as possible about the patient's subjective symptoms of discomfort and pain. The patient's general health, his personality pattern, and the local findings must be intelligently correlated, analyzed, and integrated in order to arrive at a sound diagnosis.

2. In making the clinical examination, great attention must be paid to the dynamic forces of occlusion. In order to get a clear picture of the factors involved, we must commence with a study of functional occlusion and its relation to the health of the masticatory apparatus.

At one time the skull with the perfect set of teeth (secretum apertum) was set up as the ideal normal for both natural dentitions and artificial dentures. It was thought that when the maxillary and mandibular teeth are, from an anatomic

standpoint, in good occlusion, normal function in mastication is assured. We now recognize, however, that good intercuspation of the teeth in a static state need not necessarily be suggestive of good function. As a matter of fact, in a great many instances, proper function of the masticatory apparatus in eccentric occlusions is interfered with because of the apparently good anatomic occlusion with deep intercuspation.

Our concept of "normal occlusion" has undergone vast changes. It has evolved through a great range of anatomic variations until it has reached the present stage. From consideration of the "secretum apertum" as the ideal normal, it was widened to include many types of static occlusions that were not ideal but nevertheless normal. The concept has been further widened to include other variations in static occlusion that were considered harmonious with the skeletal structure of the head. In a great number of cases even this broader approach to the determination of the normal proved inadequate. It was realized that, while in a static state, such occlusions could be accepted as average normal based on statistical data, their function in mastication may be abnormal. It was then concluded that static occlusion as viewed on the articulator and in the mouth must be integrated with functional occlusion. Static occlusion conveys to us an idea of the meeting of the mandibular teeth with those of the maxilla after function ceases and the jaw comes to a standstill. But our goal is to establish proper biologic function whether it does or does not correspond to a particular type of average normal occlusion. Satisfactory function of the masticatory apparatus may be associated with such a wide range of static anatomic variations that we may consider the latter also satisfactory. If we substitute the term *satisfactory* function for normal function and *satisfactory static occlusion* for normal occlusion, we will easily arrive at the realization that these vary from case to case and from individual to individual. In other words, each and every individual possesses an occlusion that is characteristic of the particular and peculiar process of development of the individual. This means that each and every case should be individualized with regard to diagnosis, prognosis, and treatment planning.

Scientifically established averages for normality and abnormality are very useful in broadening our mind and widening the horizon of our scientific thinking. They help us to correlate, coordinate, and integrate all the factors involved in a particular case into a sound and well-founded diagnosis. But close as a certain case analysis may be to a well-established average, the latter cannot serve as a substitute. We cannot use statistical data as a therapeutic agent for the patient. When we study the anatomy of skulls or of the muscles of mastication, the appearance of their individual features may be very similar. But their function during life is vastly different. The same difference prevails between the superficial appearance of static occlusion and the function we might anticipate from it on the basis of this appearance. The dynamic efficiency or inefficiency, the health or disease factors inherent in these dynamic forces, may be and usually are vastly different from what the static occlusion might have indicated. Proper function of the masticatory apparatus and the adjacent and associated structures is essential to the establishment and maintenance of oral health. That is why functional occlusion should predominate in our thinking when we study a given case with

a view to establishing a diagnosis. This scientific approach is of paramount importance in our clinical studies of temporomandibular joint syndromes.

In human beings, the mastication of food is effected by a grinding, chopping motion. The grinding is performed by a lateral movement of the mandible to the maxilla, which differs greatly in range as well as in magnitude in different individuals. It is effected by the movement of the buccal cusps of the mandibular teeth laterally to make contact with the buccal cusps of the maxillary teeth, followed by a return to centric occlusion. This is called the masticatory stroke.

A great majority of our cases of temporomandibular joint disturbances are in boys and girls in the adolescent stage. On clinical examination we usually find that one or more of the six-year molars are missing and that the adjacent teeth have migrated considerably from their positions in the intact dental arches. When one or more of the six-year molars is lost and no space maintainer or permanent replacement has been provided, deterioration and complete dislocation of the masticatory apparatus follow. This is because the teeth adjacent to the lost one commence to migrate. The tooth situated distally from the lost one moves mesially by inclination (not bodily). The tooth situated on the mesial side moves distally, also by inclination. The second or twelve-year molar drifts mesially, and the second bicuspid drifts in a distal direction. The migration of the twelve-year molar is particularly pronounced if the loss of the six-year molar occurred before the second molar erupted. If the migration of the second molar and second bicuspid is not arrested in time, it leads to the development of a pathologic pattern of occlusion.

This may be considered as a readjustment or a readaptation of the occlusion to function under new environmental conditions. At first, the efficiency of the masticatory stroke is slightly reduced by the new pathologic cusp relationship. Later on, it may become disorganized to an extent that the patient may begin to substitute the up-and-down chopping motion in mastication for the masticatory stroke. As the pathologic pattern of occlusion progresses, it may be followed by a complete disorganization of the masticatory apparatus with complications in the temporomandibular joint. This phenomenon is so frequently observed in relation to temporomandibular joint disturbances, and with such regularity of symptoms, that we may regard malocclusion of the teeth and dysfunction of the joints as being almost synonymous.

Of course, when we speak here of malocclusion, we do not refer to the old concept of static or anatomic mutual cusp relationship of the maxillary and mandibular teeth. Our attention is centered on active malocclusion which manifests itself in function. Not only does migration of teeth interfere with proper function of the masticatory apparatus in lateral, protrusive, and intermediate movements of the mandible, but it also affects the static positional relationship of the mandible to the maxilla. In these instances where six-year molars have been absent without replacement, the cusp relationship deteriorates so as to interfere with the masticatory stroke. This, in turn, creates a tremendous strain upon the temporomandibular joint structures with a resulting traumatic inflammatory process. In some instances, the pathologic reaction in the joint serves as a guide for the occlusion to readjust itself to another pattern less strenuous and less painful.

As time goes on, readaptation to new environmental conditions takes place in the joints as well as in the occlusion. In this way, a compromise is reached by nature, in which the efficiency of the masticatory apparatus is reduced. The patient, however, no longer experiences painful sensations in the joints and is no longer conscious of discomfort caused by the disharmonious occlusal relations. What the patient and, at times, the doctor consider under these circumstances a cure of the symptoms is in reality a newly developed pathologic pattern of occlusion. The freedom of the patient from pain and symptoms may last for many years. The case appears on the credit side of the doctor's ledger as a successfully treated and completed case, and the patient reports to relatives and friends about the happy outcome of the illness. Neither the patient nor the doctor is aware that this actually is not a cure but a transition from an acute traumatic inflammatory process in the joints to a more or less stabilized chronic pathologic pattern of occlusion. Only the presence of good tissue resistance makes such transitions possible.

The described course of disease is more or less typical of acute traumatic inflammatory processes with which adolescents are afflicted as a result of neglect of restorative treatment for the loss of six-year molars. This occurs between the ages of 14 and 19, when the temporomandibular joint is in its formative stage. If such neglect could be prevented, we could considerably reduce the occurrence of temporomandibular joint disturbances. The prophylactic restorative treatment would be of benefit not only in adolescence, but would prevent the reoccurrence of the joint syndrome in adult life. Careful case histories obtained from patients who are afflicted with this syndrome in adult life substantiate this point of view. They show that, in many instances, it is but a hang-over from a long dormant acute inflammatory process which first appeared in the adolescent period of life.

Thus we see that the loss of the six-year molars without restorative treatment constitutes the most important factor in the causation of joint syndromes.

The next etiologic factor of great significance is the excessively deep vertical overlap. Deep vertical overlaps may be due to undereruption of the posterior teeth or overeruption of the anterior teeth or both. The orthodontist is the qualified person to institute the appropriate treatment which, in reality, is at the same time preventive dentistry for the joint structures and periodontal tissues. Similarly, in adult patients, problems relating to bite-raising by means of restorative procedures can best be solved in consultation with orthodontists, who are in an excellent position to contribute greatly to a correct diagnosis, without which proper management of a case is inconceivable.

The labial surfaces of the lower anterior teeth may be in intimate contact with the lingual surfaces of the upper anterior teeth throughout almost their entire length. The cusp height of the posterior teeth is usually pronounced. The posterior teeth may or may not be in correct intercuspation. This type of vertical overlap frequently proves very troublesome for the temporomandibular joints. Here, too, the masticatory stroke in trituration of food is interfered with, as in the instance of loss of the six-year molars with tooth migration.

The handicap manifests itself in the following manner. Every time the mandible attempts a lateral excursion, it performs two movements simultaneously,

one laterally and the other in a protrusive direction. It is more appropriate to say that a lateral mandibular excursion represents a movement sideways associated with a protrusion. On the working side, where the buccal cusps of the mandibular teeth come into contact with those of the maxillary teeth, the condyle head performs what we may call a vertical axiorotational movement. On the opposite side of the dental arch, on the so-called balancing side, the behavior of the condyle head is of a different nature. Here, the condyle head moves downward, forward, and slightly medially. This three-dimensional movement cannot be performed by the patient possessing the type of vertical overlap under discussion. The intimacy of surface contact (not point contact) between the facies labialis of the lower anterior teeth and facies lingualis of the upper anterior teeth locks the occlusion and precludes this three-dimensional movement. The patient must then adapt himself to reducing the food to small particles mainly by a chopping motion. Careful clinical investigation suggests that patients with this type of occlusion experience difficulty even with the chopping motion. In these instances of excessively deep vertical overlaps, in which the incisal edges of the upper anterior teeth do not flare forward but are directed straight downward, the incisive protrusive relation is associated with an opening component greater than usual, and the patient must retrude the mandible abruptly to place the posterior teeth in a favorable position for the chopping duty. The transition from incision with the anterior teeth to chopping with the posterior teeth is too abrupt, and the retrusion is performed, without any tooth surface guidance. In consequence, it exerts a tenseness and strain in the temporomandibular joint structures.

That this is true is indicated by information elicited from a great number of patients, especially the younger ones, between the ages of 14 and 20 years. These patients were selected from among those who did not call at the clinic for treatment of joint disturbances, but were coming regularly for operative and prophylactic dental treatment. Whenever they presented this type of deep vertical overlap, they were interrogated regarding their ability in mastication. Many of them stated that they experienced a kind of tired feeling in the jaws after a meal. Later on in life, in adolescents with this type of malocclusion, either periodontal disease attacks the anterior teeth, or attrition of the labial surfaces of the lower teeth and lingual surfaces of the upper teeth is manifest. Either of these conditions alleviates the strain upon the temporomandibular joint structures. As a matter of fact, periodontal disease may frequently be a manifestation of nature's attempt to get teeth that are in the way out of the way. This holds true with regard to many cases of malocclusion that precede the setting in of periodontal disease. Attrition is another way of nature's eliminating interferences with mastication. Figuratively speaking, if the occlusal surfaces of the teeth were covered with interarticular cartilage, most of the joint disturbances would be eliminated. A free play of small-range movement would then be present in the anterior portion of the articulation (articulation of teeth) as there is in the posterior portion (joint articulation). It may be that nature has provided the upper and lower teeth with elastic periodontal structures to achieve this objective in some measure.

As further proof that acute joint disturbances are mostly caused by interferences with the masticatory stroke we may cite here several important clinical observations. Patients afflicted with advanced alveoloclasia associated with pronounced mobility of all teeth (but with complete absence of pain in the periodontal structures) seldom suffer from acute joint disturbances. This is probably because the mobility of all the teeth permits a readjustment of the masticatory stroke, thereby freeing the joint tissues from strain.

Another relevant clinical observation could be cited from the field of full denture prosthesis. Acute temporomandibular joint syndromes, as we observe them in adolescent and adult patients with natural dentitions, are almost totally absent in full denture wearers. This is not to infer even remotely that if a partial denture wearer is afflicted by the joint syndrome, full denture construction may be suggested as a therapeutic means. In malocclude full artificial dentures, the traumatic occlusion manifests itself in pain and resorption in the denture-supporting structures but not in the joints, because it is not the condyle heads that shift in their glenoid fossae, but the dentures upon their respective alveolar processes.

I am aware that our literature is rich in reports of case histories of just this type of traumatic inflammatory conditions in the joint structures in full denture patients. The literature is generous in ascribing, in great numbers, cases of deafness, tinnitus, neuralgia, vertigo, headaches, stuffiness in the ears, and pain on the side of the head, face, and in the mastoid region to "mandibular overclosure." Experience has led me to believe that, in the majority of cases, such reports are the result of improper diagnosis. Some of these cases are caused by hidden foci of infection. Others are a local manifestation of a general condition; patients may also be afflicted with a general rheumatic or arthritic condition that happens to be more acutely manifested in the temporomandibular joint than in any other joint of the body.

In still other cases, a chronic joint condition represents a hang-over from a pre-existing acute inflammatory process during adolescent or early adult life. The patient wearing full dentures may, in these instances, experience clicking or crepitation in the joint that is not associated with pain. Yet the patient who is emotionally upset may magnify this condition to the point of complaining of pain of a vague nature. A number of these patients get into a habit of moving the mandible about all day long, listening to the clicking or crepitation just to find out how much worse it is getting. A tired feeling in the joint and pain may develop as a result of strain from this type of overactivity of the mandible. Cause and effect form a vicious circle which leads to aggravation of the patient's condition.

The masticatory stroke, or lateral chewing motion, which, as we have demonstrated, has a very important bearing on the etiologic factors of temporomandibular joint disturbances as well as on the incipient stages of periodontal disease, must be subjected to further careful and searching investigation.

SUMMARY AND CONCLUSIONS

1. Function of the temporomandibular joint has been considered in the light of knowledge of its anatomy and physiology. The mechanistic concepts have

served their purpose and must now give way to or be extended by information obtained from studies of dynamic clinical manifestations in health and disease. Functional activity of the masticatory apparatus cannot be reproduced by an articulator. But for purposes of practical full denture construction a good adjustable articulator may reproduce movements more or less closely approximating the equivalent movements of the mandible.

2. Roentgenographic evidence of abnormalities in function has been examined and found wanting because of faulty interpretation based on misconceptions and errors inherent in the orthodox method of securing temporomandibular joint roentgenograms, that is, by first having the patient clench the teeth (closed mouth) and then interposing a 30 to 35 mm. block between the incisal edges of the anterior teeth (open mouth). There is no intention to belittle the importance of roentgenographic studies for diagnosis in medicine or in dentistry. Roentgenography is one of the greatest history-making advances in the art and science of healing. The criticisms are directed solely against the incorrect orthodox way of securing temporomandibular joint roentgenograms and their misinterpretation. A technique for obtaining standardized roentgenographic records of the temporomandibular joint in the various positions assumed by the mandible has been presented so that we may have a sound basis for the scientific conduct of future studies.

3. The importance of clinical diagnosis in the study of temporomandibular joint syndromes is stressed. The patient as a whole individual is considered. The role of occlusion in etiology is discussed, and it is concluded that the concept of "perfect occlusion" viewed from the standpoint of static normal intercuspation of the posterior teeth and a normal overlap of the anterior teeth is antiquated. We have observed many patients with edge-to-edge bite, and many other patients with a mild underbite (Angle Class 3), which function excellently. We have had under observation for many years patients with individual teeth completely out of alignment in labial, buccal, or lingual version. Yet such dentitions rendered an excellent service to their hosts for nearly a lifetime.

A. Most cases of joint disturbances are caused by the early loss of the six-year molars which are not replaced by space maintainers and later by the most suitable artificial substitutes.

B. The next important etiologic factor in joint disturbances is represented by malocclusions characterized by excessively deep vertical overlaps. Some of these overlaps are due to overeruption of the anterior teeth, others to undereruption of the posterior teeth, or both.

C. Interference in the performance of the masticatory stroke with all types of malocclusions is a frequent cause for joint disturbances.

D. Overclosure of the mandible (per se) with natural dentitions or with artificial dentures is rarely responsible for joint disturbances, and we, therefore, too often resort to bite-raising procedures when it is contraindicated from a biologic standpoint.

Since the goal in rendering a health service is the restoration and maintenance of proper function and not anatomic perfection, diagnosis and treatment management should primarily be based on biologic efficiency in function.

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SPEECH CONSIDERATIONS IN CLEFT PALATE PROSTHESIS

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IT IS generally agreed by surgeons and dentists today that the success of a surgical or prosthetic reconstruction of a cleft palate will be determined largely by the effectiveness with which it subserves the speech process. The current surgical point of view is seen in Ivy's statement[10]: "The chief reason for closure of the cleft in the palate is to render good speech possible." Harkins,[11] a prosthodontist, said, "The most important function of a prosthesis is its use in the acquisition of better speech. It is for this reason that the prosthesis constructed for cleft palate patients is called a speech aid rather than an obturator, or denture, or an appliance." The disordered speech resulting from the palatal deficiency frequently seems more important to the cleft palate patient than do the general health and cosmetic problems. It is not enough then for the oral prosthetist to restore occlusion and to provide a separation between the oral and nasal cavities. To assist in speech training, the prosthesis must be designed to take advantage of those movements which occur in the naso-oro-pharyngeal area during speech production. As Fitz-Gibbon,[4] Cooper,[3] and Harkins[7] have pointed out, to do this the cleft palate prosthodontist should be familiar with the physiology of speech production.

PHYSIOLOGY OF SPEECH PRODUCTION

A study of the mechanism used in speaking shows that speech is an overlaid function and that we have no speech "organs" per se. A careful analysis of the physiologic processes which contribute to speech production indicates that not only are basic biologic acts greatly modified for speech, but some functions appear to have been developed largely for speech production.[18] Such an analysis indicates that the following five types of physiologic activity contribute to the speaking act: respiration, phonation, resonation, articulation, and integration.

The motive power for speech is supplied by respiration. The air which has been inhaled is held in the lungs and gradually exhaled through the larynx, where the second major physiologic event takes place. For the production of certain sounds, the vowels and the voiced consonants, the vocal folds are adducted, and the outgoing air stream sets them in vibration, producing what is called "phonation." In the production of other sounds, the vocal folds are abducted and phonation does not occur; hence, these sounds are classified as voiceless sounds. The sound patterns set up at the laryngeal level are modified by the resonation which occurs

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in the pharyngeal, oral, and nasal cavities. It should be noted here that for only three of the English speech sounds, the nasal consonants (m, n, and ng as in "sing"), does the nose function as the primary resonating cavity. For all others, such nasal resonance is minimized by the occlusion of the nasopharyngeal port. Articulation takes place in the oral cavity where the tongue alters its position to place varying degrees of obstruction in the way of the outgoing air stream, in the case of some sounds, or to modify the size and shape of the resonating cavities in the production of other sounds. The integrating function of the central nervous system coordinates the actions of this complex neuromuscular system to produce the consonants, vowels, and diphthongs of which speech is comprised.

PHONETICS OF SPEECH PRODUCTION

The distinguishing characteristics of the consonant sounds are determined by (1) the degree of obstruction placed in the way of the outgoing air stream, (2) the locus of this obstruction, and (3) the presence or absence of vocal fold vibration. Table I indicates the manner in which the twenty-five consonants are produced.

TABLE I. CLASSIFICATION OF THE CONSONANTS

LOCUS OF OBSTRUCTION	DEGREE OF OBSTRUCTION				
	COMPLETE OBSTRUCTION		PARTIAL OBSTRUCTION		
			ORALS		NASALS (VOICED)
	VOICELESS	VOICED	VOICELESS	VOICED	
Bilabial	p	b	wh	w	m
Labiodental			f	v	
Linguadental			th	th	
Alveolar	t	d	s	z,l	n
Postalveolar	ch	j	sh	zh,r	
Palatal				y	
Velar	k	g			ng
Glottal			h		

Notes:
1. In producing t, d, ch, j, voiced and voiceless th, s, z, l, sh, zh, r, and n, the *tip* of the tongue approximates the indicated oral area to produce the obstruction.
2. In producing k, g, and ng, the *back* of the tongue is employed.
3. In producing "y" (as in "yes"), the tongue is arched toward the alveolar ridge.
4. The tongue is relaxed in the production of the other consonants.

Kantner and West[30] pointed out that ". . . there is no sharp dividing line between vowels and consonants . . . . Each sound, except the nasals, is delivered through an oral orifice of a certain size, and it would be possible to arrange these sounds in order from (s), the one with the smallest orifice, to (a) (as in father), the one with the largest opening. As long as the opening is small enough that friction noises are produced by it when the air stream passes through, the sound is, by definition, a consonant. When the opening becomes large enough that

friction noises are not produced, the sound is classified as a vowel." Fairbanks[3] defined a vowel as "a voiced speech sound in which the vocal cord tone is selectively modified as it passes through resonance cavities of the throat and head. There is relatively little obstruction of the breath stream. Different vowels are produced by changing the characteristics of these cavities, and probably the most important factor in this process is variation of tongue position."

Vowels are generally classified according to (1) that portion of the tongue which is elevated to modify the oral cavity, i.e., front, middle, and back, and (2) the height of the tongue, i.e., high and low. Table II classifies the important vowel sounds according to these determinants.

TABLE II. CLASSIFICATION OF IMPORTANT VOWELS*

RELATIVE HEIGHT OF TONGUE	PART OF TONGUE ELEVATED					
	FRONT		MIDDLE		BACK	
High	ē	eat			o͞o	too
To	ĭ	it			o͝o	book
	ĕ	bet	ŭ	cut	ô	ball
Low	ă	bat	å	above	ä	father

*There are fifteen common American vowels. This chart includes only the ten on which the speech correctionist is likely to drill the cleft palate patient.
The symbols used are the diacritical marks as described in Webster's Collegiate Dictionary.

In addition to the consonants and vowels, there are five diphthongs in general American speech. These sounds are produced by rapidly blending two vowel elements. They are heard in the words foal, fowl, fail, file, and foil.[3]

To some extent, perhaps, all five of the physiologic activities are affected by a cleft palate; however, it is the interference with resonation and articulation which produces the greatest speech mutilations. After reviewing the available experimental and clinical evidence, McDonald and Baker[21] concluded that a complete closure of the nasopharyngeal port is not a prerequisite to nonnasal speech. They have summarized data which lead to the conclusion that: "There is a critical point in the degree of closure of the nasopharynx . . . . If this critical point is not reached, nasality will occur." They pointed out that this critical point is probably not a fixed point along the dimension between the border of the velum and the wall of the pharynx. Such factors as the position of the tongue and mandible and the degree of patency of the oropharynx affect the determination of this critical point. Usually the untreated cleft palate patient cannot effect the degree of closure which is necessary to prevented unwanted nasal resonance from occurring. Hence, the speech is likely to be hypernasal.

The articulation of the cleft palate patient will be adversely affected also. In normal speech production the plosive consonants (p,b,t,d,k,g) are produced by

suddenly releasing air which has been momentarily impounded in the oral cavity. Certain other sounds, such as f, v, th, s, and z, are made by forcing the air stream through a narrow orifice created in the oral cavity. Because of the opening into the nasal cavity, the cleft palate patient cannot develop the intraoral air pressure which is necessary for the production of these sounds. He attempts to compensate for these conditions by overretracting and overelevating the dorsum of the tongue and, thus, develops undesirable patterns of lingual activity. This seems to result in even greater distortion of speech.

SPEECH REQUIREMENTS OF A PROSTHESIS

The cleft palate prosthodontist can assist the speech correctionist in obtaining better speech for cleft palate patients by constructing an appliance which will permit the oral cavity to function as a resonator independently of the nasal cavity and which will permit adequate articulatory movements. Such an appliance should be composed of three main portions: (1) the palatal section, which would occlude any cleft in the hard palate, carry the clasps for retention, and also carry any necessary dental replacements; (2) the velar section (sometimes referred to as the "tailpiece"), which would cover any cleft in the soft palate and would support the pharyngeal section (sometimes referred to as the "bulb"); and (3) the pharyngeal section, which provides the contact for the contracted constrictors of the pharynx.

Palatal Section.—As can be seen in Table I, linguadental or lingua-alveolar approximations are important in the production of such speech sounds as th, s, z, sh, ch, j, t, d, and n. Fymbo[5] has shown that the incidence of such dental anomalies as interdental spaces (particularly among the upper eight anterior teeth) and open or closed vertical dimension is much higher among speech defectives than among normal speakers. West and associates[24] noted that the recessive mandible presents problems in the production of b, p, m, s, and z and the prognathic mandible makes it difficult to produce the s, z, f, v, and th sounds. To enable the patient to produce these sounds accurately and easily, therefore, any missing teeth should be replaced, and the maxillary incisors should be restored to their normal relationship with the mandibular incisors by either orthodontic or prosthetic procedures. Sometimes in postsurgical cases, where there has been a compression of the maxillary arches, teeth erupt far inside the normal arch position. If such teeth are permitted to protrude through the prosthesis, they interfere with those movements of the tip of the tongue which are necessary to produce speech sounds at a conversational rate. While the technique of building an appliance which covers these teeth does produce a smooth lingual surface, it frequently reduces the volume of the oral cavity and thus affects speech adversely. Some prosthetists[10] prefer to solve this problem by grinding the teeth down until they are flush with the lingual surface of the appliance and placing thimble or jacket crowns on them. It is not, of course, the intention of the writer to discuss the dental considerations in any of these procedures, but rather to cite the desirability of having an appliance with a smooth lingual surface and no critical reduction in the volume of the oral cavity. As is pointed out by Harkins and

Ivy,[13] the appliance should be vaulted as much as is anatomically and prosthetically possible. This vaulting not only permits more nearly normal tongue movements, but approximates the normal resonance characteristics of the oral cavity. The palatal section should contain sufficient clasps for firmly anchoring the prosthesis to the teeth, since adequate retention is necessary to prevent movements of the appliance which might interfere with speech.

Velar Section.—The contruction of the velar section poses a problem which must be given careful attention for those patients whose soft palates are not united at the midline. In normal mouths, the contractions of the levator palati and tensor palati which occur during speaking result in the tensing, elevating, and retracting of the velum. These movements contribute to the nasopharyngeal closure. In those cases where the soft palate is not united in the midline, contraction of these muscles results in a lateral movement of the velar tissue. Unless special attention is given to this problem when the prosthesis is constructed, this lateral movement may pull the velar tissue away from the appliance and thus produce a leak into the nasal cavity. Such a "leak" may result in hypernasality and excessive nasal emission. The velar section, too, should be placed as high as is anatomically and prosthetically possible.

Pharyngeal Section.—The success with which a prosthesis subserves the speech function is determined largely by the size, shape, and location of the "bulb" or pharyngeal section. In order to seal off the nose from the mouth and pharynx during speech, the pharyngeal section must be located at the point of maximum constriction of the pharynx, and it must be large enough and of such a shape as to allow the pharyngeal walls to embrace it when they are contracted.[12] Studies of cleft palate and normal subjects have shown that, during speech, the reduction in the lumen of the pharynx is produced by the anterior movement of the posterior walls and the mesial movement of the lateral walls, and that there is considerable variation in these movements from one individual to another. It has been suggested that the bulb be oriented to the tubercle of the atlas bone. This is not a dependable landmark, however, since as the work of Harrington[14] and Wolfe[25] indicates, the tubercle of the atlas is not necessarily the level at which the anterior movement of the posterior pharyngeal wall is greatest. It is not advisable to overextend the pharyngeal section in the superior-inferior dimension in an attempt to be certain of taking advantage of the constriction of the pharynx. The researches of Hixon[15] and of Kaltenborn[19] seem to indicate that having a narrow space between the dorsum of the tongue and the palate during vowel production is an important cause of nasality. Over-infraextension of the pharyngeal section obviously would reduce the dimension between the dorsum of the tongue and the palate and would modify markedly the resonance characteristics of the oropharyngeal cavity. Over-supraextension into the nasopharynx might result in a denasal voice quality.[12] It is suggested, therefore, that the pharyngeal section be located at the area of maximal constriction of the pharynx as determined by muscle trimming produced during deglutition, turning the head, and so forth. The size and shape of the bulb should be determined largely by the amount of constriction during these acts also. This will usually mean that the pharyngeal

walls may not forcefully contact the bulb during speaking; however, this is not serious since, as was pointed out earlier, a complete velar pharyngeal closure is not essential for nonnasal speech. The bulb must be large enough, however, to permit the critical degree of closure to be reached when the pharyngeal musculature contracts during speech.

The speech correctionist finds it advantageous to have the bulb portion of the appliance constructed of some transparent, easily modifiable material, such as clear acrylic resin. The transparency permits him to observe the action of the pharyngeal constrictors during vocalization. It has been our experience that, after a few weeks of intensive speech training, the development of the pharyngeal constrictors necessitates a reduction in the size of the bulb. The indications for this reduction are: (1) a complaint of "fullness" or soreness in the throat, (2) difficulty in breathing through the nose, and (3) denasality, i.e., an absence of nasal resonance on the nasal consonants m, n, and ng. When the speech correctionist reports these indications, the prosthetist should study the bulb to determine in what area and by how much it should be reduced.

AGE FOR PROSTHETIC INTERVENTION

The speech correctionist is interested in preventing the development and habituation of undesirable articulatory movements and the development of the psychosocial maladjustments which are natural outgrowths of a gross speech difference. This does not mean, however, that the palate must be closed during the first months of life. A study of Table III shows that only the simplest of the speech sounds are mastered by the average child during the first three years.[22] This means that so far as speech is concerned, palatal reconstruction can safely be postponed until this age or later. Any sound mutilations which do develop can be eliminated through speech therapy. The speech correctionist would agree with Ivy[17] that there is little validity in the argument that the palate must be closed early to prevent the development of speech defects which will be difficult to eliminate later.

TABLE III. ORDER IN WHICH THE SPEECH SOUNDS ARE LEARNED

TYPE OF SOUND	AGE AT WHICH AVERAGE CHILD HAS MASTERED IT
Vowels	During first year
Labials	3 years
Dentals and gutterals	3½ to 4 years
Labiodentals	5 years
Complicated tongue sounds	During sixth year
Sibilants and blends	During seventh year

A further study of Table III reveals that after the third year the average child begins learning those consonants which are important for the intelligibility of speech. The speech correctionist would like to plan a speech training program which would prevent the development of badly distorted speech patterns during

this period. Therefore, in those cases where a prosthetic restoration is the method of choice, the speech correctionist recommends that it be supplied as soon as the deciduous teeth have erupted sufficiently to provide retention and the patient is emotionally capable of cooperation.[8,9,12]

Even in those cases where surgical reconstruction is thought to be the method of choice, there is a growing tendency to postpone surgery on the palate until the growth of approximately five-sixths of the total maxillary width has taken place, i.e., at least until the end of the fourth year of life.[2,6,23] It would seem desirable from the standpoint of speech development to supply a temporary prosthesis for the child when he is approximately 2½ years of age. The use of spring wire clasps permits frequent adjustments and apparently does not restrict growth.[8,10,12] The patient can be re-evaluated between 4 and 5 years of age to determine whether a surgical or prosthetic reconstruction of the palate is indicated.

MANAGEMENT OF SURGICAL "FAILURES"

In some postoperative cases there remains a velar insufficiency or immobility which appears to preclude the development of good speech. When further surgical retropositioning of the palate is contraindicated, the cleft palate prosthodontist is requested to construct a prosthesis. Where the prosthetist finds certain indications present, he may ask the surgeon to redivide the palate.[13] Since it has been suggested that a complete nasopharyngeal closure is not necessary for nonnasal speech and that an improper use of the tongue may produce the undesirable voice quality,[21] the speech pathologist would advise a thorough study of the patient's speech habits before a prosthesis is recommended. Such a study would (1) determine the tongue and mandibular positions used in producing the vowels and (2) analyze the articulatory movements. If these are found to be grossly defective, the speech pathologist might recommend a period of experimental speech training before proceeding with prosthetic reconstruction.

SUMMARY

One of the major functions of an oral prosthesis for cleft palate patients is to subserve speech. To aid the prosthetist in understanding the speech process, a brief description of the physiology and phonetics of speech production is presented. The speech considerations to be observed in constructing a prosthesis may be summarized as follows:

I. Construction of the prosthesis
   A. *Palatal section:*
      1. Should establish occlusion between the anterior maxillary and mandibular teeth to aid in the production of the labiodental, linguadental, and lingua-alveolar sounds.
      2. Should be free from obstructions (such as protruding malpositioned teeth) which would interfere with the free movement of the tip of the tongue.
      3. Should be vaulted to produce an oral cavity of as near normal size as possible.

4. Should provide adequate retention so that movements of the appliance will not interfere with speaking.

B. *Velar section:*

1. Should be constructed to compensate for lateral movement of velar tissue in unoperated or redivided cases in order to prevent leakage of air or sound into the nasal cavities during speaking.
2. Should be placed as high as is anatomically and prosthetically possible to avoid interference with tongue movements and to restore an oral cavity of normal size.
3. Should provide a sturdy support for the pharyngeal section.

C. *Pharyngeal section:*

1. Should be located at the point of maximum constriction of the pharynx as determined by muscle trimming during deglutition.
2. Should be large enough for the pharyngeal musculature to grasp during deglutition and to approximate during speech production.
3. Should not be over-infraextended, i.e., it should not extend inferiorly into the oropharynx and, thus, reduce the size of this important resonating cavity, nor should it be over-supraextended.
4. Should be constructed of some readily modifiable material which will permit adjustment as muscular development results from speech training.
5. Should be constructed of some transparent material to enable the speech pathologist to observe the muscular adjustments taking place during vocalization.

II. Age factor in prosthesis

The prosthesis can be employed to prevent the development of serious speech defects. The speech pathologist recommends that temporary prostheses be supplied for children as soon as the deciduous teeth have erupted sufficiently to provide retention and the child will cooperate.

III. Management of postoperative cases

Before a prosthesis is constructed for a patient whose palate is insufficient or immobile, a thorough study of the lingual and mandibular movements employed in speech production should be made by a speech pathologist. On his recommendation experimental speech training should be provided for certain patients before a prosthesis is supplied.

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News and Notes

ANNOUNCEMENTS

The American Denture Society will meet at the Shoreham Hotel in Washington, D.C., Oct. 13 and 14, 1951.

The meeting of the American Academy of Restorative Dentistry will be held in Chicago at the Stevens Hotel on Feb. 2 and 3, 1952.

The Annual Postgraduate Clinic of the District of Columbia Dental Society will be held on March 9 to 12, 1952, at the Shoreham Hotel, Washington, D.C.